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SKYWAYS

By

CHARLES GILBERT HALL

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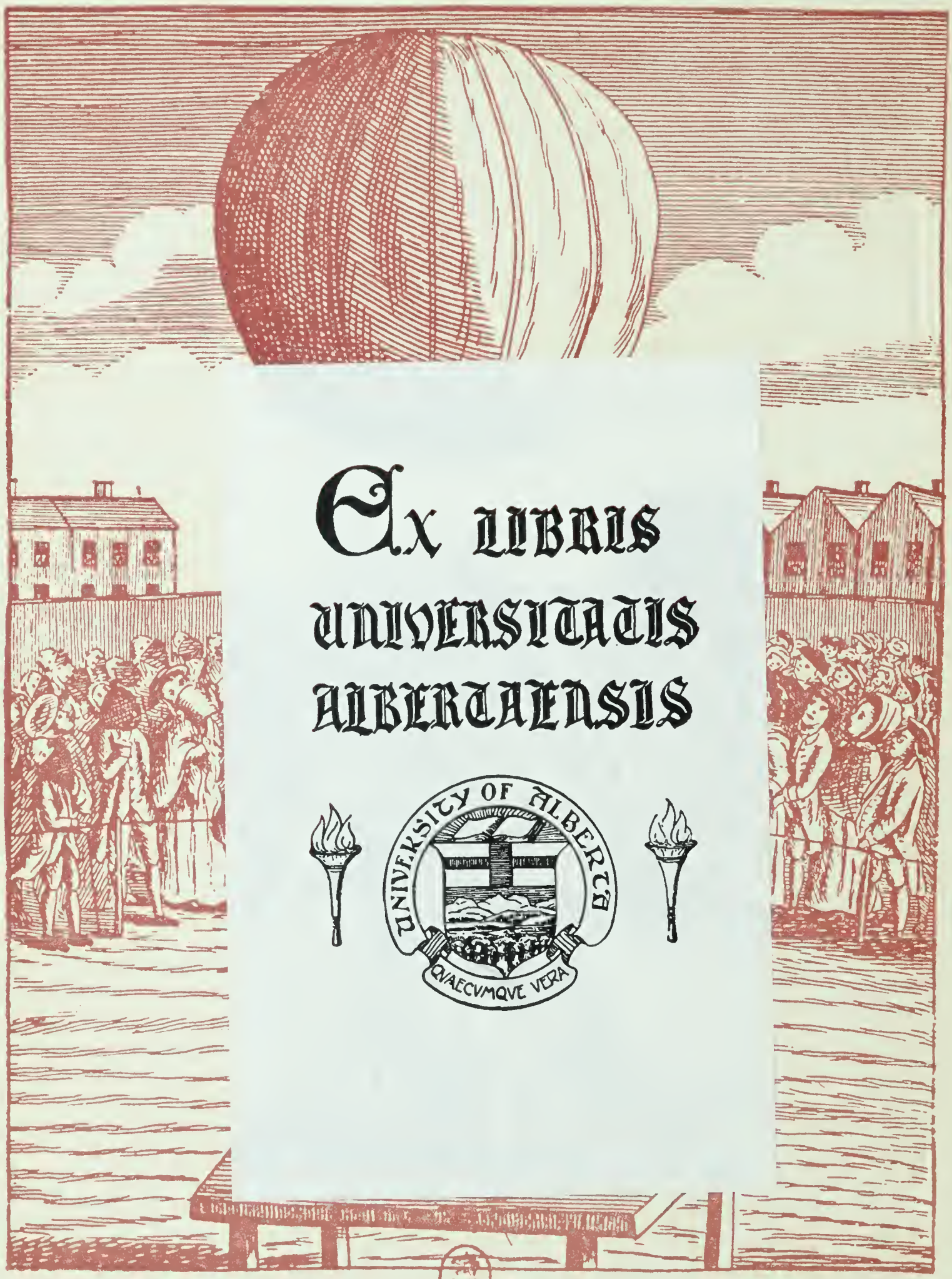

THE AIR BALLOON.

Which was Launched in the Artillery ground Nov.r 25. 1783.

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THE Macmillan COMPANY

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CHARLES GILBERT HALL

NEW YORK · 1941

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TO LUCY AND HER MOTHER

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They shall mount up with wings as eagles.

—Isaiah XL. 31

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An Ancient Persian Idea of Flight

1

The Spirit of the Air

ONCE upon a time there was a king, and he had a little son. And all the courtiers and the servants knew that nothing which the little prince wanted was to be kept from him, though sometimes he seemed to want impossible things.

One day, as he saw the flying birds about the palace gardens, the prince cried: "I want to fly! I want to fly!" and the king's servants ran to quiet him.

But the king said: "It cannot be, my son; men do not fly." Still the little prince would not be comforted or contented.

One day he found himself in a great forest, far from the palace gates. He saw an old, old man coming toward him. "What dost thou here,

young prince?" the old man said. "Tell me what thy wish is and I will attend to it." And the princeling said: "I wish that I might fly."

Then the old man said to him: "Hear thou! I am Almaran, the Wise. I can do all things. But know, oh prince, that what you ask is hard. You must wander through all this forest—the Forest of Difficulty—and across yonder plains—the Plains of Discontent. Turn you home, oh prince, and try not the journey."

But the prince would not turn back; so the venerable man took him by the hand. Long days they wandered through the forest. Long nights they traveled over the scorching plains, until the prince, sore and weary, often said: "I can go no more." But Almaran always replied: "But you can, my prince. Strive on." At last he pointed to where came a woman, whose shining garments flashed in the sun. She was very beautiful.

"Through the Forest of Difficulty," she said, "and across the Plains of Discontent—that is the road for all who would dwell on high. Now take my hand, oh prince!" Then they left the old man of wisdom leaning on his staff, and moved on until their garments floated about them; then hand in hand the little prince and his lovely guardian were wafted on high beyond Almaran's sight.

So today, on the silver wings of the whirring airplanes, and hovering about the stately airships, if you have the seeing eye and if you believe in fairies, as all wise people should, you will see the flutter of shining garments and the waving of triumphant, joyful hands, where the prince rides triumphant, *The Spirit of the Air*.

All men who have sought to study the laws of flight have had to spend long and difficult years in the Forest of Difficulty and on the

Plains of Discontent. And many of them—most of them—have had little but failure to show for all their effort.

Such efforts began many centuries ago. In Ancient Greece there was a man who said: "I can fly to Athens. I have a dove, a wooden dove, that can fly. I can set it in motion, and away it goes!" But no one listened; they thought he was out of his mind. He was Archytas of Tarentum, and we now think that he had a clockwork, or something of that kind, hidden in the dove, or possibly a hidden pocket of some lightweight gas.

The Dove of Archytas

From the time of Archytas to the day when the first airplane carried its somewhat worried passenger above the dunes of Kitty Hawk, there has been more or less superstition attached to travel through the air. The Greeks had a legend about it which they held in high esteem—of the flight of Daedalus which angered the gods and led to the destruction of his son. Daedalus, the story says, was to blame. He was told that if he would build wings for himself and his son, Icarus, they could fly

above the entangling meshes of King Minos' labyrinth. The wings were of feathers, the fastening was of wax. Icarus flew so close to the sun that the wax melted, and he fell into what is still known as the Icarian Sea.

Icarus Takes a Fall

So, for many centuries, there was little doubt that man was too weak to support himself in the air; and that the gods would take sure offense if he tried to do so. Nevertheless, a few bold spirits were always ready to rise above fear and see what could be done.

The lack of mechanical inventions such as we now find available make these earlier devices seem to us strangely impossible. Neither

steam nor gas engines had been invented, and the ancients had no such metals as we use today in the form of lightweight alloys. Nor did they know enough about the laws of flight—the laws of aerodynamics, as we call them—to make their efforts successful. At first, about all they could do was to strap wings to their bodies in imitation of the birds. Each man thus had to supply his own power and flap his own wings. With such contraptions, the bold experimenters leaped from cliffs, hilltops, and towers, meeting, like Darius Green, with very little success.

There were many of these experimenters. In the reign of the Emperor Manuel Comnenus, a learned man of Constantinople arranged a long white robe that was stiffened with rods, and with it jumped from a high tower, in a brisk wind; he landed safely. It was the first use of the parachute of which the world has any record.

The World's First Parachute

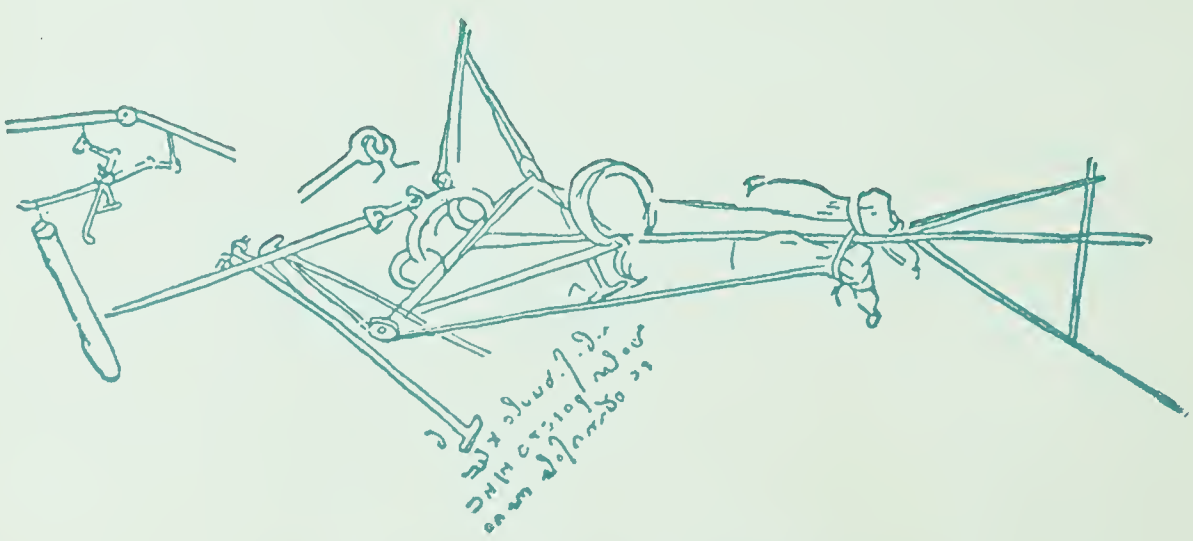
In the year 1065, just a year before the Normans came to England, a monk, named Oliver of Malmesbury, made a gliding machine, of which we have but a slight description, and with it jumped from the summit of a tower.

In Portugal Bartholomeu de Guzman got the attention of the king and persuaded him to listen to his plans. They were by no means simple ones. He believed that if he had a big bellows to blow him along through the sky, and if a magnet, large enough to draw him, were

placed at the point which he wanted to reach, he could travel through the air. Nothing was ever done to prove it, as the king seems to have forgotten Guzman before the experiment could be tried.

As these men thus studied and experimented and sometimes risked their lives, the period known as the Italian Renaissance approached. The art of printing with movable type was perfected and books were being published; magnificent pictures were being painted; beautiful forms were being sculptured; Columbus was about to discover America; and Marco Polo had come home from far Cathay to tell wondrous, unbelievable tales. Art and adventure were advancing hand in hand. It was a day of doing and daring; the imagination ran riot and men's curiosity demanded something to feed upon.

Of all the men of that time, one of the most daring was Leonardo da Vinci. His genius ran in many lines of activity; he was a silversmith, a painter, a sculptor, an architect, and an engineer. Leonardo believed



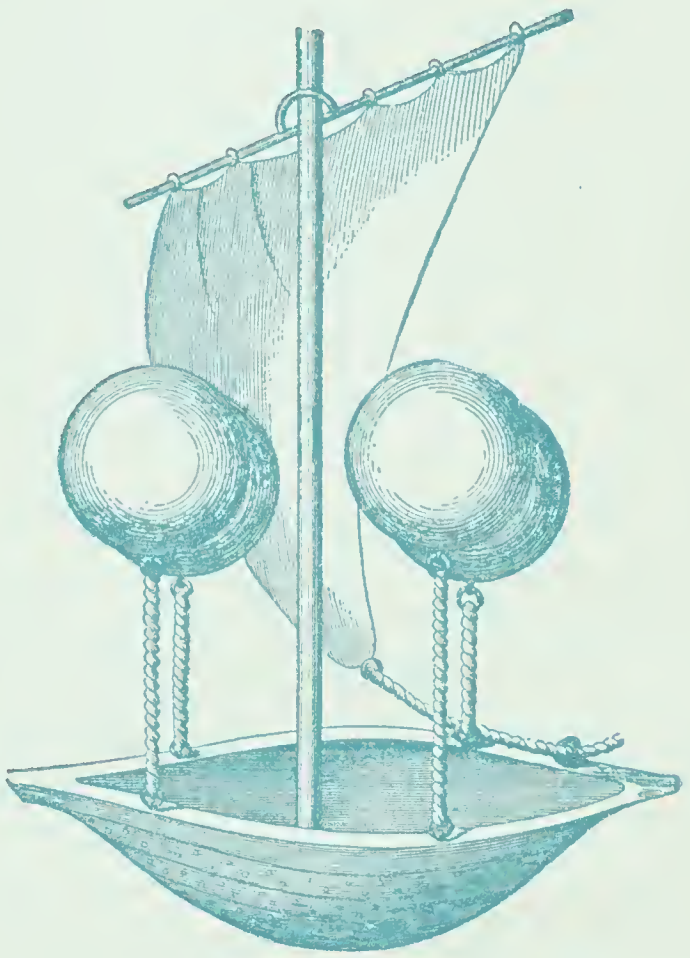
Leaf from da Vinci's Sketchbook

that men could fly. About the year 1475 he began to give the question his serious attention, and he has left us some interesting sketches of how he thought it should be done. The drawings show an arrangement of wings and oars, operated by a system of pulleys and stirrups. Many

men have thought that if Leonardo had lived in a day when such things as lightweight alloys had been known and if some such propelling force as our explosive engines use had been within his reach, he might have flown. This is unlikely. For without such things as the air tables that the Wright brothers created, and without the facts about the laws of the air that have since been built up around these tables, he could not have succeeded. His science was wrong. But he made a great contribution for students of flight in his analysis of bird flight and bird structure.

Model of da Vinci's Flying Machine

Not much advance was made in the art of flying for some time after da Vinci died, although a number of experiments were made. About 1650 Francisco de Lana, a Jesuit father, planned a boat that was to be somewhat the shape of half a walnut shell. He proposed to attach to it four hollow globes of copper, from which the air had been exhausted. This, he believed, would cause his strange vessel to ascend. He proposed, then, to erect a small sail with which to propel it.



Guidotti, of Lucca, another Italian, made wings of whalebone and feathers, but could do little with them.

Now it began to be pretty clearly understood that man would not make much progress until he learned a good deal more about the air and its properties. Naturally he began to wonder about the birds. How do they sustain themselves in this dangerous and mysterious element? Men didn't know the answer! How does the air react to movement, weight, and force? No man could tell!

So men began to ask questions. What shape should a man's wings have? What kind of feathers would carry him farthest? How should a man's wings be fastened on? How should he flap them? Sir George Cayley was called the Father of British Aeronautics. He built a helicopter in 1809 that was hand propelled, and he also used propellers on a balloon in 1816. It was Cayley who first devised a *cambered* wing, slightly bent to a convex curve, like the wing of a bird.

Some people believed that wings should be flapped straight up and down. Others held that a bird uses his wings somewhat as we use the oars on a boat, describing something like the figure eight.

In 1842, William S. Henson patented a steam-driven monoplane which he proposed to propel by the use of three-foot paddles. If it had flown, aviation would have received a great impetus.

In 1848, John Stringfellow, who had been Henson's associate, and who had given much time to the study of aeronautics, built a model

A Hawk's Wings, Motionless

that was supported by wings and equipped with two screw propellers. It was the first airplane that ever flew.

In 1867, Professor J. B. Pettigrew decided that wings act somewhat as we have suggested—like oars. He believed that a bird's wings are thrown backwards, broadside on, coming forward again with the edge of the wing cleaving the air. He thought that the wings probably turned or twisted something like an auger or screw, not unlike the action of our modern propellers.

These men, by their experiments, learned many things about the laws of flight. They found that a bird doesn't fly just because he has feathers. Bumblebees, bats, and a thousand small insects fly, with no more feathers than you or I have. They also learned that a bird doesn't fly just because he can flap his wings. He carries many things in that small head of his besides that. He must keep his balance and not get turned upside down in a sudden gust of wind. He must keep out of the way of other birds. He must know exactly how to take the utmost advantage of rising air currents that are going his way. He must know about speed, direction, and distances. He must know how to stop, and how to alight skillfully.

Men discovered, too, that feathers don't make a bird weigh any less. He is just as heavy as any other little animal of his size. This discovery led to another and quite important one: That far from being undesirable, weight is actually necessary to flight. The air is a tremendously,

A Hawk's Wings as He Takes the Air

wickedly treacherous element. It can tear up trees by the roots, shatter whole cities, sweep over miles of country in a minute, and leave only wreckage in its wake.

They began to realize, too, that the reason men hadn't learned to fly was, among other things, the fact that air has slight *density*. When we walk on land, it is solid, holding up the smallest feet. When we swim, the water is displaced, to be sure, but it still remains to support us, and we can float on its surface. We need more support in the water, of course, because the water *gives!* So, when we're swimming, we use both hands and feet.

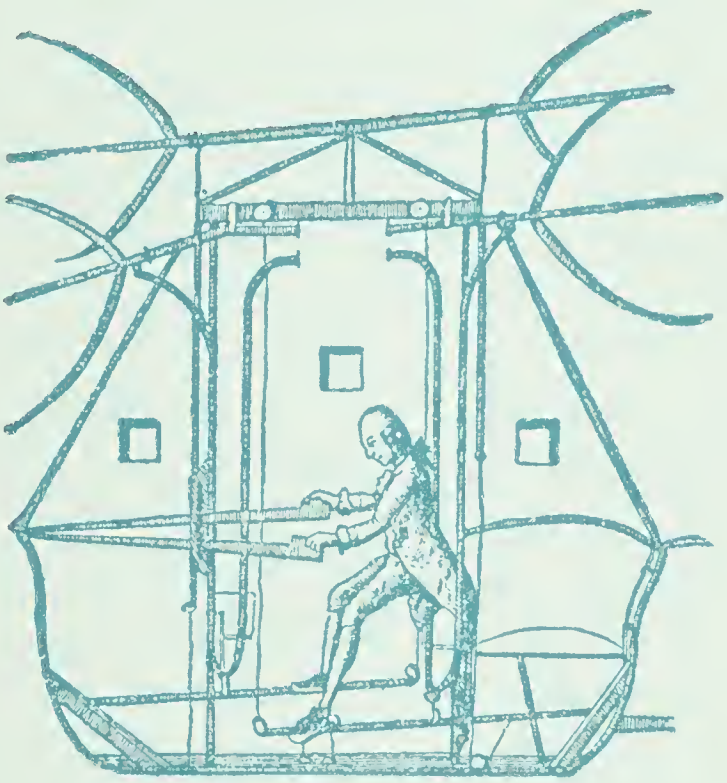
But in the air! Why, water is eight hundred times as dense as air! Is it any wonder that the birds need wings that have a large supporting surface? Look at your kitten's dainty feet; she uses them only on land. Then look at a duck's broad webs—he uses them to paddle in the water, displacing enough water to move him along through it. Then compare with the mighty pinions of a hawk! Puss has little pads, not an inch across. The duck has feet big enough for a small boat. But the hawk! Which of you knows the wingspread of a hawk?

So with all of its lightness and uncertainties, it was agreed that the air is very strong, and that weight and solidity were going to be necessary in any machine which man might make that would be able to cope with the air.

Yet the sky has always been a free road. Very often it offers the shortest distance between two points. Man should be entitled to traverse it. The courage, skill, powers of invention, and energy of these early experimenters were challenged. *What of the Air?* they cried.

Yes: *What of the Air?* Someone has said that if men had been able

to see the air and its currents and disturbances and stresses, we never should have dared to fly. But fly we did! Sir George Cayley decided that a flying surface must have considerable stability and considerable strength. Others began to study the laws that govern the lifting weight of surfaces, and especially the action of the air upon surfaces that are curved. They would have been much surprised if they could have seen our airplanes of today, made of metal, weighing many tons, and flying two or three hundred miles an hour!



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Up in a Balloon!

WITH the development of some of the problems we have told of in the foregoing chapter, it began to grow clear that until more was known about the air and the laws that govern its movements, not much progress could be made in flying.

The attention of certain men was now directed to the use of balloons, or lighter-than-air vehicles. At first, these were the spherical or pear-shaped balloons that are familiar to most of us in pictures or otherwise. These balloons had no steering gear and no means of propelling them. They merely served as a means of ascent; no one, going up in one of them, could tell anything about where he would come down. It was hoped that the various questions of direction and propulsion might be more speed-

ily answered when man was once able to get his feet off the ground.

It was in 1783 that the first successful balloons were made. Two brothers, named Montgolfier, were responsible for this. Their father was a wealthy paper maker who lived in the ancient city of Avignon. The brothers had become much interested in the problem of man's ability to fly. They had noticed that straws, bits of paper, and other objects of small weight rise readily enough when held over a fire. While they were not quite certain what caused this, they thought it might be possible that the smoke contained some property of lightness which carried them upward. Not for some time afterward did they learn that it was the heated air, which is lighter than air that is cold, that caused the phenomenon. If a little smoke, thought the young men, could make a small object rise so readily, why couldn't larger objects be made to rise by the simple means of making a larger smoke?

The first experiments were made in secret. The people of that day were extremely superstitious; it wasn't thought to be safe to let the public know what was going on. So in a large closed room in their father's paper mills the two brothers set to work. They filled small paper bags with smoke; while they watched the bags float lazily to the ceiling, they tried to learn something of what made them rise, what kept them afloat, and what laws governed their movements.

Finally, the Montgolfiers made a small balloon of silk, and set up smoke under it, much as we might light a fire under a paper balloon today. Then they tried linen, lined with paper. At Annonay, forty miles from the city of Lyons, in June, 1783, using a fire of chopped straw, they sent up a linen globe a hundred five feet in circumference, which stayed in the air ten minutes.

The brothers now felt that it was time to take the public into their confidence. They built a balloon of silk. The Montgolfiers had made extended inquiries and experiments to determine what kind of smoke was best. They finally decided that smoke from chopped wool and wet straw would make a balloon rise farthest. A mighty fire was built beneath it, and a large crowd gathered to watch the quivering mass as it slowly filled with the heated air. When they had filled it with smoke, it took eight men to hold it down.

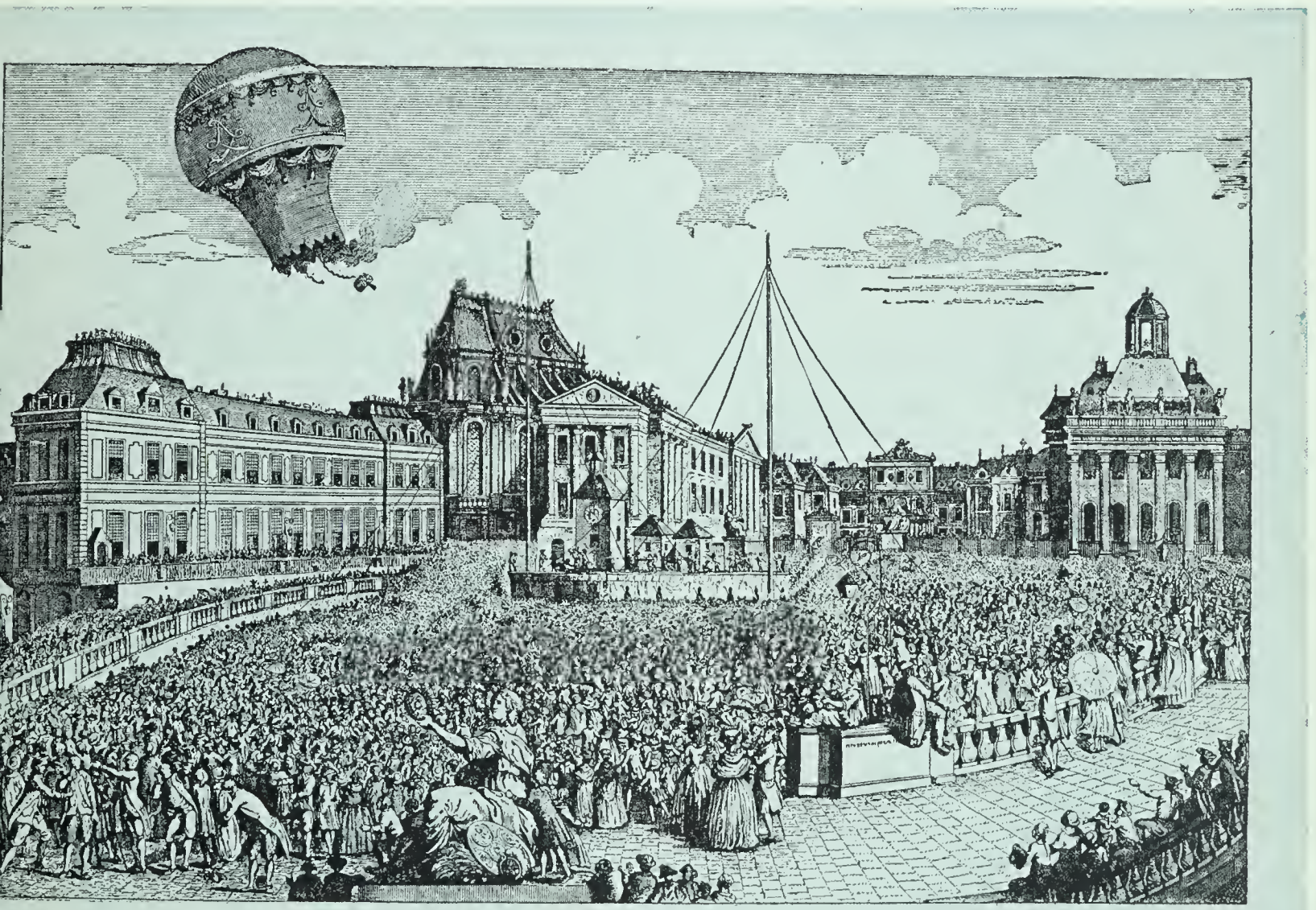
The Montgolfiers, Joseph and Etienne

As the fire began to smolder and send off dense wreaths of smoke, and as the mass of silken fabric writhed, filled, and tugged, it seemed to the startled people that it was possessed of life. In ten minutes it

rose, floated through the air, went up six thousand feet, and traveled one and a half miles. Frightened at the unusual sight whose cause was unexplained, the crowd took to its heels and ran.

In August, 1783, a busy year for the balloonists, they gave an exhibition before the king at Versailles. Besides his majesty, the queen, the court, and a great assemblage of notables were present.

No one went up in these first balloons. No one knew what would happen if such a thing were tried. You probably couldn't get your breath at all, up so high. Even if you did come down alive, you would



Flight of the Montgolfiers, Versailles, 1783

never be the same again. But the Montgolfiers were unwilling to give up until they had learned exactly what could be done. It seemed to them that a balloon that couldn't carry anyone in it was of very little value.

So, in building the balloon that they were to show before the king, they arranged for a quaint experiment. They hung a large basket beneath the balloon, and in the basket placed the very first aeronauts ever known to history! And who do you think they were? A sheep, a duck, and a little French rooster which crowed! In the excitement that attended getting them into the basket, the sheep stepped on the rooster, injuring his right wing. But aside from this, the three puzzled little aviators came down again, none the worse for their trip and greatly to the surprise of everyone present.

This balloon was brilliantly decorated. Figures of *fleur-de-lis*, which was the king's own flower, with portraits of the king, were painted on its silken sides, and a great band around its middle displayed the twelve mystic signs of the zodiac.

The crowd was an enthusiastic one; when the balloon returned to earth and it was learned that no harm had come to its small voyagers, the time seemed to have arrived for a man to make the trip. There was some talk of offering freedom to a condemned convict, if one could be found who would make the attempt. Finally Jean Pilâtre de Rozier, one of the king's officers, came forward. He made his first voyage in a captive fire balloon, that is, a balloon attached to a cable and carrying beneath it a platform, or grate, on which a fire could be made.

De Rozier took with him a supply of chopped straw and wool with which to keep the fire going; he was also supplied with water and a

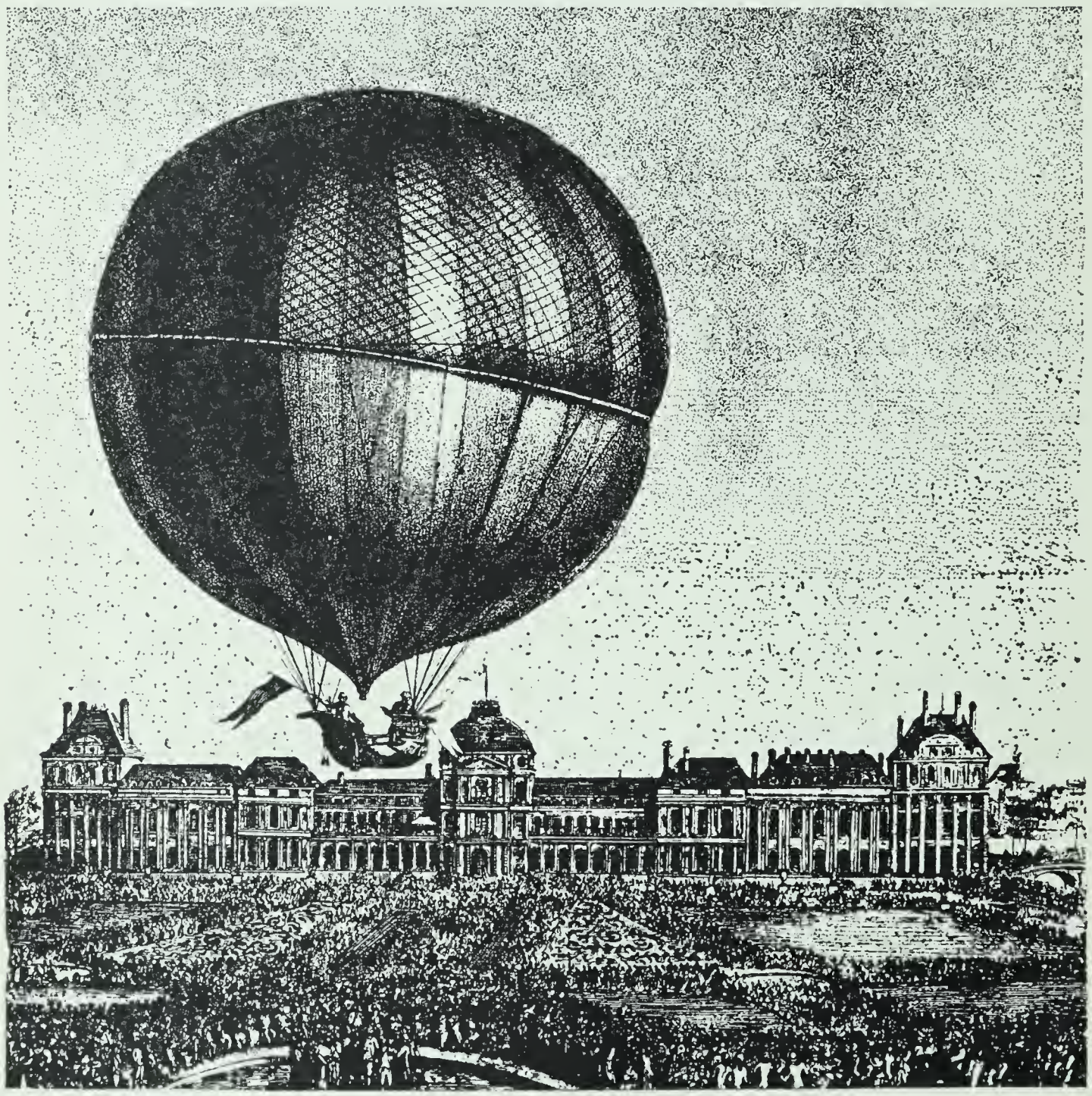
sponge, so that he could put the fire out when he was ready to come down. On a second flight de Rozier took with him as a companion the Marquis d'Arlandes. When they came down the two men were black as coal heavers; they were covered with smoke and grime.

Ticket of Admission to De Rozier's Flight—Note the Initials of the Aeronaut and His Companion

But that's about all of the smoke story. The idea of using smoke to send up balloons didn't last long; hydrogen gas soon took its place. Later, coal gas was used, and today helium is the best agency of which we know. A man named Charles, of the University of Paris, put an end to the use of smoke by suggesting that it wasn't the smoke that had made the balloons rise, but the heated air, which was lighter than the surrounding atmosphere. He suggested that a much better method would be the use of *hydrogen*. In 1766, seventeen years earlier, the English scientist, Cavendish, had discovered a gas that he called *inflam-*

mable air. We now call it hydrogen. And he announced to the world that the new gas was *seven times as light as air!*

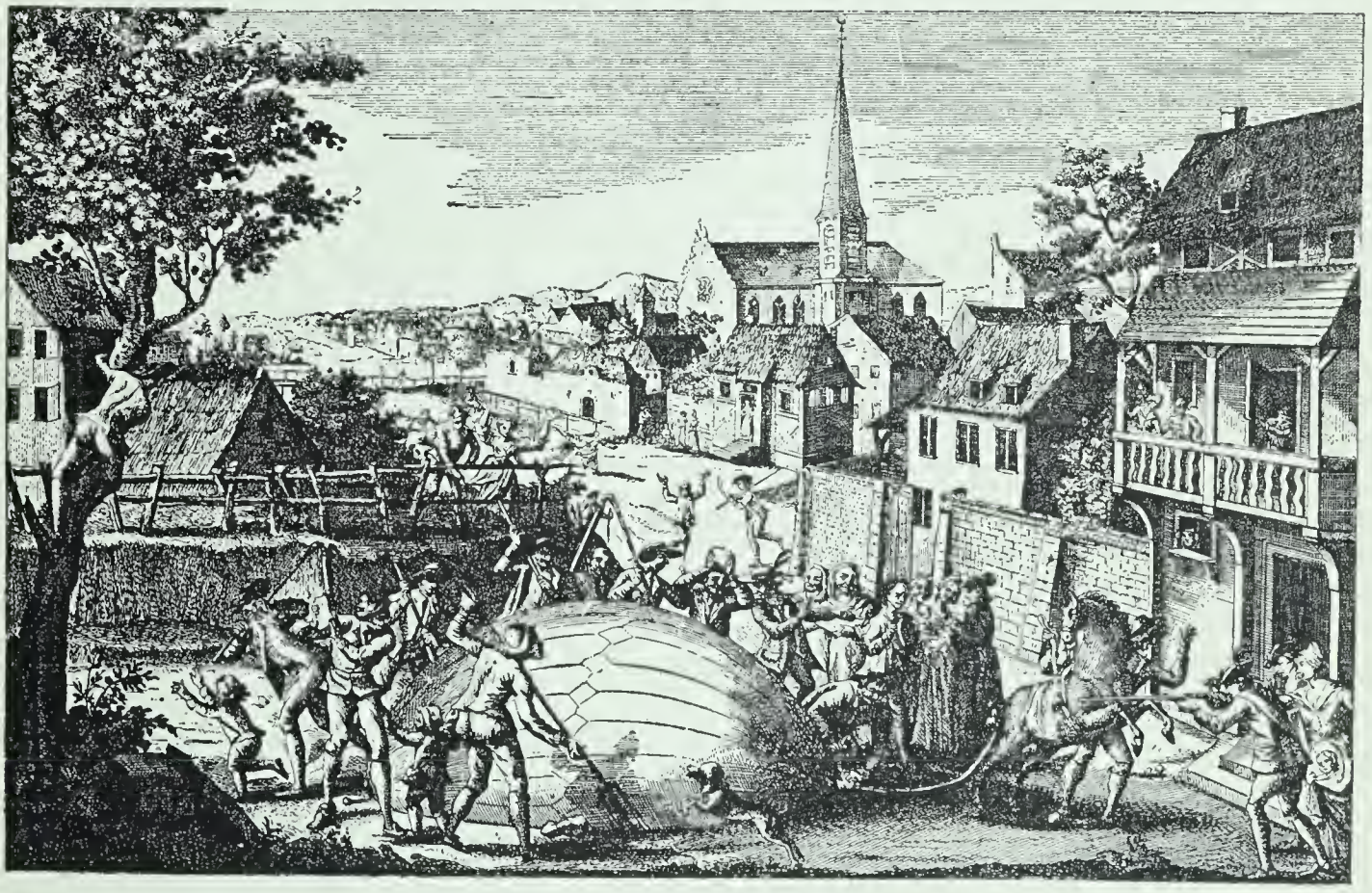
So Professor Charles built a balloon of thin silk and over it placed a coat of varnish made from an elastic gum; he inflated it with the new gas. The interest shown was very great—so great, in fact, that bulletins were issued daily during the inflation of the silken bag. So great was the crowd which gathered that the balloon was secretly removed a distance



Professor Charles and His Hydrogen Balloon

of two miles to the Champ de Mars, to protect it from harm. When it was released, it rose to a height of three thousand feet, and traveled a distance of fifteen miles.

Later the same year, Monsieur Charles, with a companion, rose from the Tuileries Gardens in a hydrogen balloon. As he attempted to land, peasants who saw the balloon thought it was a strange creature from some unknown world. As it descended, dragging through the tree tops, they ran at it with pitchforks, gashing the silken canvas and scaring the poor professor so badly that he had to take to his heels.



Professor Charles and the Peasants

Men now vied with one another to show their daring by making these ascents, and their names, as of great heroes, rang throughout France. There was much excitement at the ascensions; great crowds

THE AIR BALLOON.

Which was Launched in the Artillery ground Nov.r 25. 1783.

gathered at each performance, including everyone from the king and his courtiers to the rudest peasant or townsman.

Some of the balloons were very large, and they made some remarkable flights. In London, an Italian named Zambecarri made an ascent, and flew forty-eight miles. In Philadelphia, the American Philosophical Society was making researches on the subject at the time of the work being done by the Montgolfiers. The Society finally persuaded a man to ascend in a device that consisted of a large number of small balloons—forty-seven of them, filled with hydrogen and attached to a car or cage. The aeronaut stayed in the air ten minutes; at the end of that time he was forced to descend. He succeeded in doing this by cutting gashes in the small balloons in order to get down before he reached the river, which he was then approaching.

In England a great deal of interest was shown; an Italian named Lunardi went up many times. In an attempt to fly across the English Channel, he built a complicated arrangement of oars and paddle-wheels, in the hope that he could thus propel the balloon. He took a cat up with him. But neither Lunardi nor the cat was able to steer the ship, and they had to come down without coming anywhere near the Channel.

Charles Green was an English aeronaut who made a famous flight from London to Germany, a distance of five hundred miles, in 1836. He used coal gas instead of hydrogen, and this method was followed by other balloonists for many years.

The largest balloon on record was built at Lyons, France, in 1784. It was said to be a hundred feet in diameter and had a capacity of 500,000

cubic feet. With a straw fire, it went up 3,000 feet with seven passengers and remained in the air seventeen minutes.

One of the largest balloons in history was called *Le Géant*. It could carry forty passengers. But it could not be steered, and the forty people never knew where they were going to land. It was equipped with a rudder, and propelled by oars that were worked by the passengers and crew. It was said that in still weather the ship could thus be turned about. This was the first real attempt to make the balloon a useful means of travel. But it didn't work very well. In London, in the year 1864, a balloon was built that contained a large stove in which straw was burned. It had a tall chimney; the stove and chimney weighed nearly a thousand pounds.

Thirteen years before this the balloonist Giffard had tried the experiment successfully of flying a few miles with a balloon that he had fitted up with a small steam engine. In 1872 Dupuy de Lôme tried to use a motor fed by an electric battery; but not enough was known about electric motors to make a success of it. The same year, he put in a motor that used benzene as fuel. This motor he attached to a cigar-shaped bag that he rightly thought would more readily lend itself to steering. From this time on there were many experiments. In 1884 two Frenchmen named Krebs and Renard actually propelled an airship against the wind. Fourteen years later, in 1898, Santos-Dumont made his first flight. In 1903 he flew a nonrigid dirigible six and three-quarter miles and rounded the Eiffel Tower above wildly enthusiastic crowds. He stayed in the air an hour and a half. In 1905, he used a rigid, cigar-shaped car to which a passenger boat was slung. It had two motors, and could travel twelve miles per hour.

Globe a reostatique Lancé a paris dans le fauborg
St. Antoine le dimanche 19. 8bre 1783. il a 60 pied de diametre dans la grande
dimension et 40 dans la petite il pese 800" quatre Hommes placés Surles Cotés se sont enlevée
a la Hauteur de 400 pied il a été environ quinze minute en Lair.
A ORLEANS CHEZ PERDOUX. F. M. D.

Souvenir of an Early Flight at Orleans, France

Two Frenchmen, named Le Baudy, then built a ship for twenty passengers, which attained a speed of forty-two miles per hour. This was the end of the French advance in this direction until the opening of the World War.

It will be seen that balloons were now fast developing into what we call airships. Count Ferdinand von Zeppelin had for several years been making experiments with fully rigid dirigibles. He was a young German who had come to America during our War between the States as a Union soldier, and who was greatly interested in the use made of captive balloons for observation purposes in the Union army. Returning to Germany, his long experiments resulted in his first airship in 1900. It only flew three and one-half miles before it was wrecked. But other ships followed; in 1908 the German government came to his rescue, adopted the airship as its own, and encouraged Zeppelin to continue his efforts. Zeppelins, as the ships came to be known, played an important part in the World War. They have performed regular service between Europe and America. Their inflation in America has usually been by means of helium. This gas does not catch fire as does hydrogen, which Germany has always used to inflate dirigibles. Much interest has always been shown in the United States in the development of these lighter-than-air ships. But the heavier-than-air airplanes have developed so rapidly that their growth somewhat overshadows that of their fellow craft.

This interest in lighter-than-air machines is not new in America. The Revolutionary War had just ended and the United States government had not yet been formed, when the Philosophical Society made the experiments that are described on an earlier page. These experiments

* GEORGE WASHINGTON, *President of the United States of America,*

TO ALL TO WHOM THESE PRESENTS SHALL COME.

THE bearer hereof, Mr. Blanchard a citizen of France, proposing to aſcend in a balloon from the city of Philadelphia, at 10 o'clock, A. M. this day, to paſs in ſuch direction and to deſcend in ſuch place as circumſtances may render moſt convenient—THESE are therefore to recommend to all citizens of the United States, and others, that in his paſſage, deſcent, return or journeying elſewhere, they oppoſe no hindrance or moleſtation to the ſaid Mr. Blanchard; And, that on the contrary, they receive and aid him with that humanity and good will, which may render honor to their country, and juſtice to an individual ſo diſtinguiſhed by his efforts to eſtabliſh and advance an art, in order to make it uſeful to mankind in general.

Given under my hand and ſeal at the city of Philadelphia, this ninth day of January, one (Seal.) thouſand ſeven hundred and ninety three, and of the independence of America the ſeventeenth.

Signed GEORGE WASHINGTON.

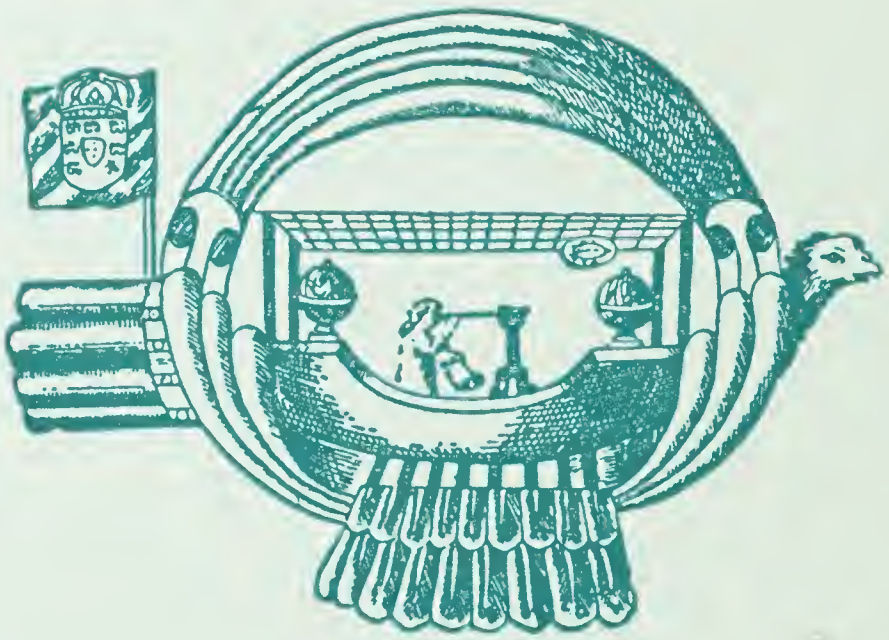
A *Perfectly Sound Safe-Conduct*

were soon followed by balloon ascensions by a Frenchman named Blanchard, who, in 1793, made the first actual balloon ascension in America. General Washington was President of the United States at that time, and was in the crowd that watched the aeronaut as he slowly drifted out of sight.

Washington was much interested in anything that would make travel easier and less slow and cumbersome in the new country of which he was the head. He joined in various enterprises, such as the building of canals, the improvement of highways, and the exploration and survey of the western wilderness. Travel was a heavy task in those days. The roads were well-nigh impassable, and the mails, when they came at all, were weeks apart. News traveled slowly; the President felt that the

growth and welfare of the nation depended largely upon the ease with which people could communicate one with another.

Washington himself was a great traveler. He had visited most of the country, going as far north as Kittery, which is in Maine, and as far south as western North Carolina. On the 157th anniversary of the establishment of the United States Post Office, an army officer in an airplane in a single day flew to every important point reached by Washington in his travels. In that one day the flier dropped a bag of mail at each of the places that it had taken Washington weeks or months of laborious travel to reach.



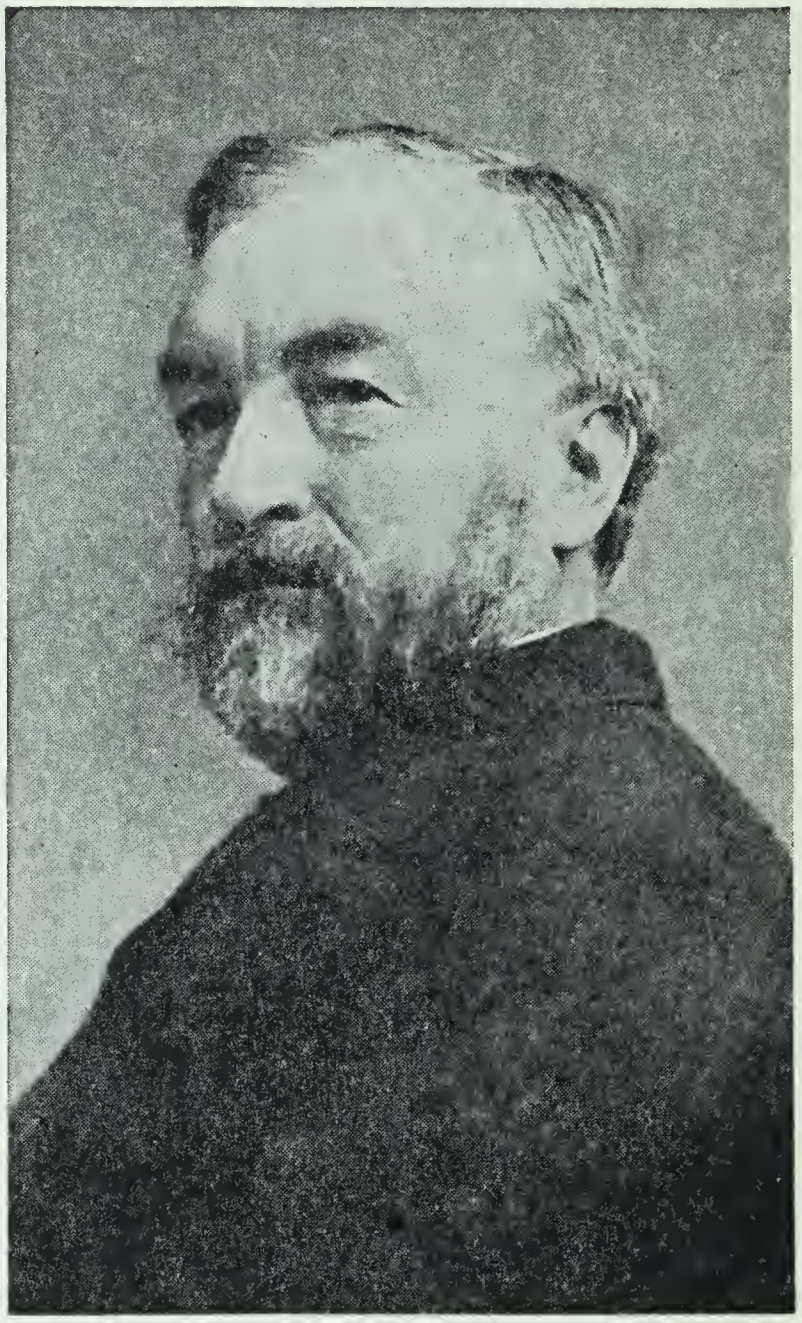
3

The Professor and the Flying Machine

WHEN I was a boy, we used to go to the creek to swim; before we went in, we would stop and pick up thin, smooth stones and skitter them through the air. One after another, every boy would see how far he could throw; those who could balance the stones just right would send them sailing halfway across the sunlit waters, where they would bounce and skip along the surface, striking it lightly in long leaps.

One day one of the boys held up a thin, flat rock. "Look here," he said, "why does this stone stay in the air so long? It is just as heavy as other stones. What makes it soar so far?" Well, that was a poser! Men had puzzled over some such problem for a good many years. What makes things fly? Balloons don't fly. They merely float or soar. Men

could understand balloons; but like Lunardi and his cat, they wanted balloons that could be steered. To steer them meant that you must first get them under way, like a boat which has to have steerage way. Lunardi tried oars and paddle wheels; and Meusnier, in France, planned the use of oars that were fixed to a revolving wheel.



Samuel Pierpont Langley

This step proved to be important. For the oars were not unlike our propellers. Still the thing wasn't complete. It wasn't yet like the stones that the boys sailed. For the boys knew something that the men didn't seem to sense. They knew that if you take a heavy, flat, smooth stone, hold its front edge just a little raised, and throw it fast and sharp, it will cut the air, press against it, and climb and soar, and come down again slowly and gracefully as it loses speed.

The difficulty was that men had not yet worked out the laws of flight. They were now slowly coming to the conclusion that the next step would be the study of air currents, winds and weights, plane surfaces and curves, drag or drift. In other words, man must study *aerodynamics*,

dealing scientifically with the action of air when force is applied to it.

One of the foremost students of these things was Samuel Pierpont Langley, head of the Smithsonian Institution, at Washington. He was a scientist and an astronomer of note. He had already made a number of scientific studies and discoveries that were well-known; he had invented an instrument so delicate that in its most highly perfected form it could detect a change in temperature of less than one millionth of a degree.

Dr. Langley now turned his attention to the study of the principles of flight. He believed firmly in the idea used by the boys when they sailed the stones—that if you drive a slightly raised surface through the air at sufficient speed, its front edge inclined slightly upward, *it will climb!* Airmen now call this the law of the *angle of incidence*. Much depends upon its proper use.

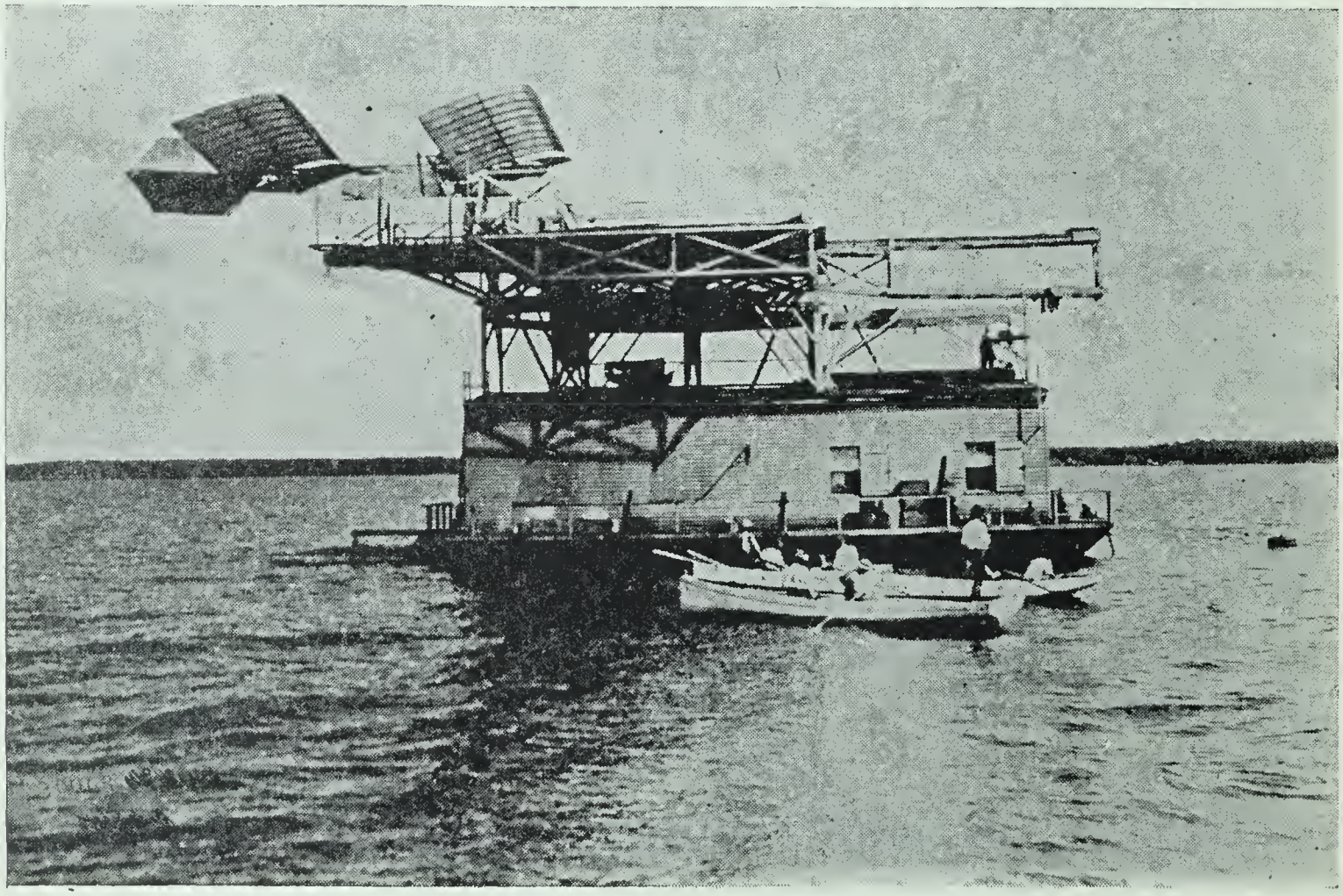
He also believed that *the faster this surface is driven, the greater the plane's lifting power and the less power required to drive it.*

Later it became apparent that if the upper surface was properly curved, the air stream would form a partial vacuum above the wing and create a suction that would hold the plane from falling. In order to create this vacuum, it was found that the air stream required that the front, or driving, edge of the wing should not be a knife-edge, as had been supposed at first, but rounded something like the drawing shown on page 112. This creates an airless space between the wing and the air stream which serves to draw the wing upward with great force.

While all this is true, it is also true that considerable power must be used to drive the plane forward. If an airplane could be built to carry an engine with power enough to drive the plane swiftly, the "lift"

would exceed the weight of the plane, together with that of the engine and the load, and the machine would fly.

But what a difference between putting your ideas on paper and actually making them work! For instance, when it came to finding power with which to propel a flying machine built upon these principles, Dr. Langley had the greatest difficulty. There were no gasoline engines in those days such as we know now, and he had to have a lightweight engine that would give considerable speed and power. With a steam engine and boiler he felt that the weight would be too great. So he went ahead, building many small machines without engines, with which he experimented in the big Smithsonian lecture room. These were really small gliders. He called them *aerodromes*. The word airplane had not yet been coined.

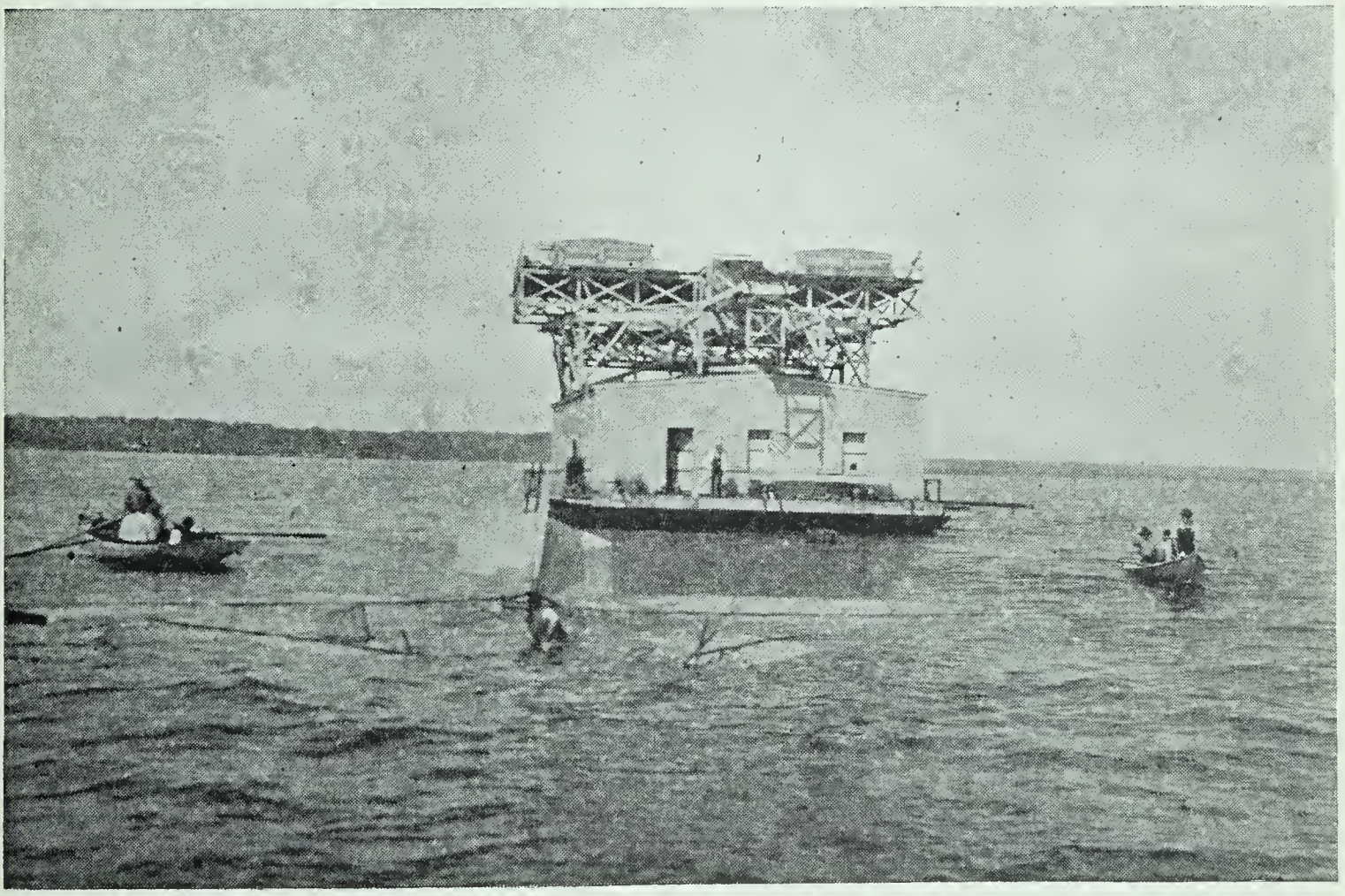


The Houseboat on the Potomac—Take-off of the First Aerodrome

Then, enthused by the progress he had made, he built a larger one. It was a rather complicated machine. In it he placed a small steam engine, yielding one horsepower and weighing only sixty ounces. For this engine he built four small copper boilers, and fitted the machine with twin screw propellers.

This was in 1896. He took the machine down the Potomac a few miles to a houseboat, from the roof of which he launched the aerodrome. It flew three thousand feet—the first flight of a heavier-than-air machine in all the world's history. In fact, the thing flew until the steam in the small boilers was exhausted and the propelling force was gone.

This, it will be seen, was not what is called *controlled* flight, in which the operator can control and change the speed and the direction of the



The Houseboat on the Potomac—After the Wreck of the Aerodrome

plane in which he rides. It was more like flying a cardboard toy to which power has been applied, or the small model planes which boys set going today for sport. But Langley felt that he had accomplished all that he had started out to do, which was to prove that a heavier-than-air machine could be made to fly. Few people indeed could then be found who would believe that such a thing was possible. In fact the world was still in that state of mind that made it quite as ready to believe in the sea serpent as in the possibility of man's being able to fly.

Still, a good deal of public interest was shown in what he had done. President McKinley got $50,000 from an old War Department appropriation for him, and he was persuaded to build an aerodrome big enough to carry a man. By October, 1903, he had completed a machine that he felt would serve.

By that time the gasoline engine had been perfected to such degree that he had Charles M. Manly, his assistant, build one. This engine developed fifty-two horse power and weighed only a hundred twenty pounds. The machine, too, was a large one, with a wing spread of 49 feet, and a weight of 830 pounds. It was proposed to launch the machine, like the smaller one that had flown before, from the top of the houseboat, anchored in the middle of the Potomac.

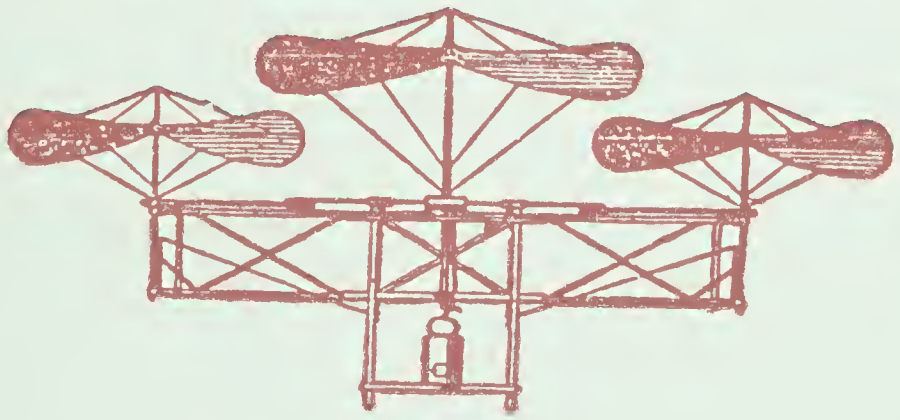
A large crowd had gathered. Many notable people were present. The engine was started. It ran smoothly. The pilot, Mr. Manly, took his seat. There was a whir and a fast run down the launching track. But at the end of the track something caught the fast-moving machine and it plunged to the river bottom.

Public opinion, ever ready to change, turned when the experiment failed. Newspapers began to print jokes about it, and people held their

sides with laughter over the idea that anyone should suppose it possible that men could fly! Notwithstanding the fact that this machine ignominiously took to the water at the end of its runway, it is still true that Langley first demonstrated the practicability of mechanical flight by heavier-than-air machines.

By December, Langley, in spite of the opposition, was ready to make another trial. But failure followed him. The machine was in place; the engine started; and down the short runway the machine took off. As it did so, the tail drew downward, the nose rose upward, and the machine sank once more! Dr. Langley's efforts were at an end.

Why the machines did not fly is not entirely clear. There is no doubt that he was working with a wrong aerodynamic formula; but it is also true that with a different engine installed, Glenn Curtiss flew the Langley machine a few years later with success.



The Wright Brothers

4

The Bishop and the Boys

ONCE upon a time there was a bishop who had a daughter and two sons. As he read to them one day, as was his custom, they looked up to hear him say:

> They shall mount up with wings as eagles;
> they shall run and not be weary; they . . .

The two boys looked at one another. On wings as eagles? They had heard of such things. There was an old book in the Bishop's library that told about how birds flew. But on wings as eagles? It might be worth while to look over the bird book again!

So they read the book and then went on about their affairs—water-wheels, kites, bows and arrows. One day the Bishop brought home a new toy. It was called a *helicopter*, he said. He opened his hands, there was a shimmer of color, a flash, and a whir, and the tiny thing rose to the ceiling, poised, and slowly fluttered to the floor.

The boys pounced on it with eager hands. It was just a little thing—a stick, two corks, a whirling piece of paper, and a rubber band. But it kept them busy for many an hour as they studied it, played with it, and finally tore it apart to see how it worked. And somehow they never forgot about the eagles and their wings.

One day, when they were grown men, they read about the German, Lilienthal, who for twenty-five years had been experimenting with gliders. Lilienthal had made wings of various kinds, and harness to fasten them to his shoulders. With these he had made over two thousand successful flights, taking off from a hillside, gliding a little way, falling, and studying about why he hadn't been able to stay longer in the air.

In this way Otto Lilienthal had learned a great many things about air currents, and about the use of curved supporting surfaces. But the work was dangerous. At last, in 1896, he made his last flight, fell, and was no more. What the boys had found was a newspaper account of his death.

"Remember that toy Father brought us years ago, Orv?" said Wilbur. Orville had been sick, and Wilbur was sitting beside his bed. "I believe there's something in this flying after all. I'll just run down and get that bird book we used to read so much." So they read, and studied, and argued, until at last their minds were made up, and they did a strange thing!

The Wrights were born mechanics. As boys, they had built a telegraph system, a turning lathe, a printing press, and an addressing machine—all from the crudest and simplest home-found materials.

"Those Wright boys are crazy," the neighbors began to say. "Wilbur is out in the back yard with a sewing machine and a lot of cream-colored sateen. And Orville is hammering away in the shop for dear life at some queer arrangement of rods and sticks. And I hear they are trying to see if they can fly! All they'll say is they're goin' away. I don't know what the Bishop can be thinkin' of, to let 'em go on so."

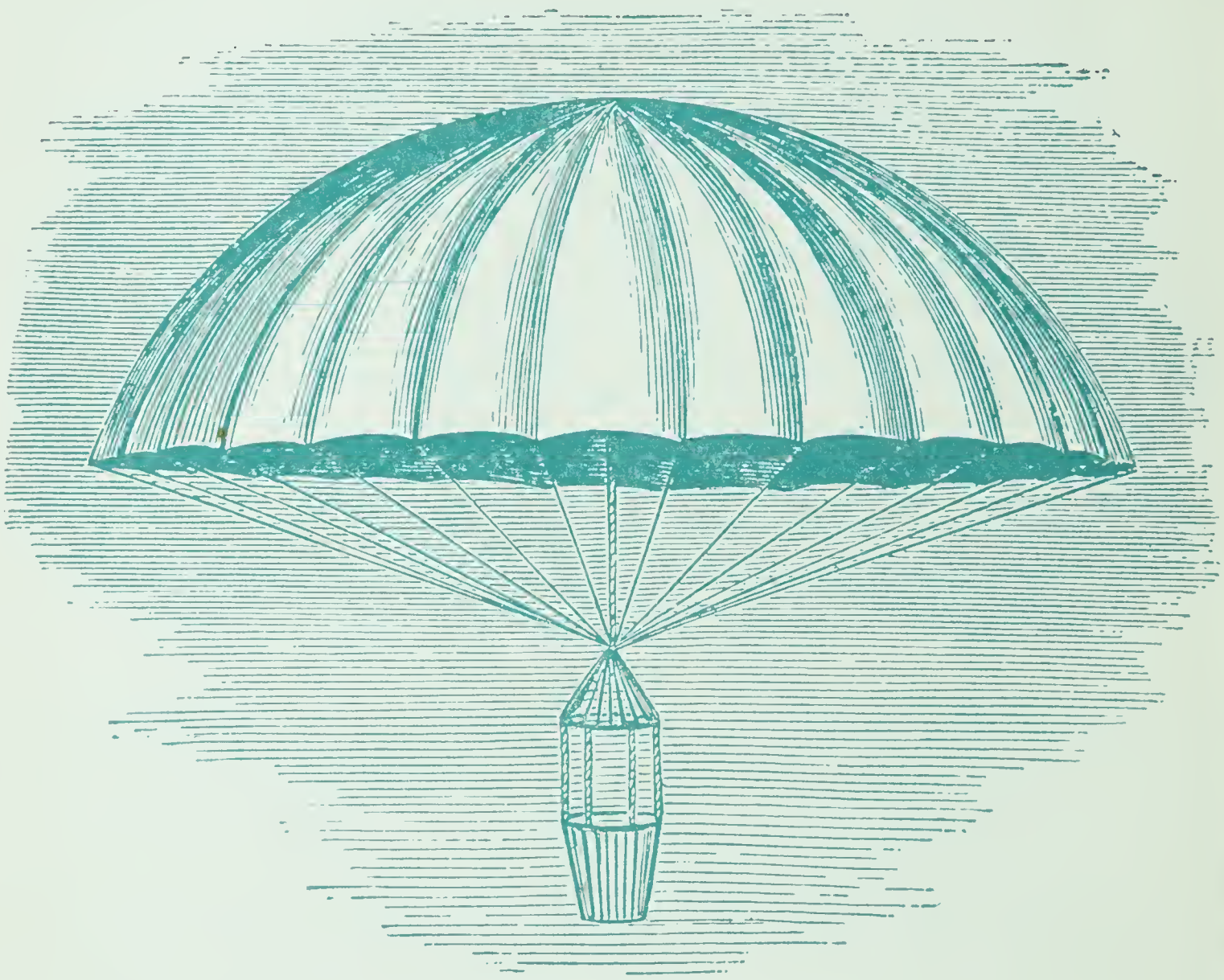
Sure enough, the sewing machine was put away at last. The shop was closed for weeks. The boys had gone on their vacation, their sister said. Gone with the cream-colored sateen, some sticks, some wire, screws, nails, and a lot of bicycle tape. But no one knew where!

They had gone to a place called Kitty Hawk. You won't find Kitty

A Modern Blimp

Hawk on most maps. It is a dreary, lonesome place of sand and sea, not far from Cape Hatteras on the Atlantic coast.

They had chosen it because it was lonely, and there would be no one to bother them there. But they had also chosen it because of its winds.



An Ancient Parachute Design

They had written the Weather Bureau at Washington, inquiring where they could find the steadiest, strongest winds, and the answer was Kitty Hawk and the country roundabout. Here the boys came year after year to work; and here they made that famous first flight.

There were two kinds of fliers at this time—people like Lilienthal, and

the Wrights' friend, Octave Chanute, both of whom thought that the best way was to *glide*, and people like Langley and Hiram Maxim, who thought you had better use power.

The Wrights were enthusiastic about gliders. They were remarkably

A Chinese "Stork" Kite

able mechanics, these Wrights, and as such had considerable advantage over Professor Langley so far as practical experience is concerned. This was made evident in the difference between Langley's complicated designs and the simplicity of the machines the Wrights now proceeded to build. In fact, so practical did their design appear that most of the early

biplanes were designed to follow the Wrights' model rather closely.

The Wrights ran a small bicycle shop in Dayton, Ohio, at this time. Here, before going to Kitty Hawk, they spent much time in experiments. They made small models of thread and bamboo, and a working model, about five feet long, of stronger materials. It was a biplane, with curved surfaces for the wings. To these wings they attached cords at the four corners, so that the wings could be twisted, or warped, to keep the model on a level keel.

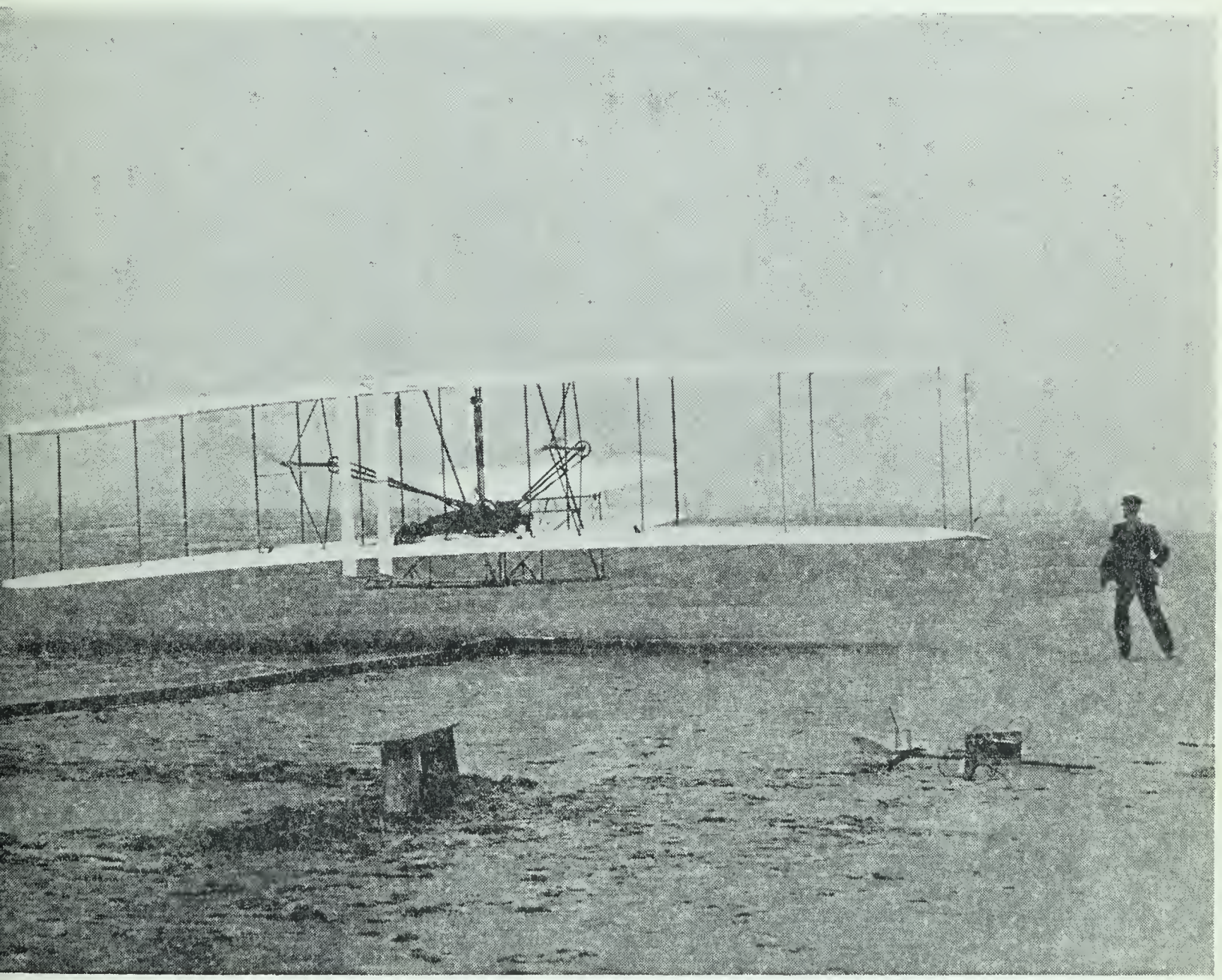
For four long years the two young men studied, argued, pondered, and read, before they felt they were ready to leave for Kitty Hawk. At Kitty Hawk the two put up a tent. Wilbur unwrapped the sateen, spruce rods, piano wires, screws, tape, and bicycle cement. And they proceeded to build a biplane.

It had neither engine, rudder, nor ailerons, but carried a small square of sail cloth in front which could be tilted to make the plane go up or down. They proposed to keep the plane in balance by bending, or warping the rear, or trailing, edge of the wings, by an arrangement of cords or wires attached to a cradle in which the operator would lie.

The brothers hardly stopped work long enough to cook their meals. They hammered and sawed and tacked sateen, until at last, although the plane was not yet complete, they decided to try it out. Tying a strong rope to its nose, they loosed it from its moorings. It was as hard to handle in the strong winds that were blowing as a balky horse, bucking and pulling in every direction.

Wilbur Wright was the first to attempt a ride on the new plane. As his plunging steed tugged at the rope, he lay flat on his face along the middle of the lower wings, stretched out in a cradlelike arrangement so built that by turning his body from side to side he could raise or lower the trailing edges of the wings. But when they tried to launch the plane

into the air, something went wrong. It looked as though Wilbur was in for a bad fall; but Orville, with helpers from the Coast-Guard Station, held the plane in control and it settled to the ground. After necessary repairs, in two or three days another flight was attempted. This time it was Orville's turn. He was more successful. In December, 1903, Orville Wright, therefore, was the first man to make an airplane flight. It lasted about twelve seconds and covered a distance of about one hundred and twenty feet.



The Amazing Miracle at Kitty Hawk, December 17, 1903

LIBRARY OF THE UNIVERSITY
OF ALBERTA

They put the glider through a hundred tests in the days that followed. Finally, they moved over to Kill Devil Hill, a near-by sand dune that is a hundred feet high. Postmaster Tate, with whom the boys now boarded, came over to help. He and one of the Wrights, holding the tips of the wings, would run down the sandy steep against the wind; the rider would turn and twist his hips to bend the wings; and the glider would reach a speed of ten to fifteen miles an hour.

It reached the point where they could manage the machine so well that they could land safely even when going at the rate of twenty miles an hour. They demonstrated beyond a doubt that the plane had a lifting power in the teeth of a good breeze that would keep it aloft as long as they could keep it under control.

They now returned to Dayton, determined to work things out, no matter how long it might take. Most of the supposedly scientific basis on which flight at that time was founded was unsound. There was little or no literature on the subject, but they got hold of Langley's air tables and studied and pondered. They had heard that there were books on flight in French and German, and they began to study those two languages, so that they might find out what had been learned by other men.

At this time the longest flight ever known by a glider carrying a man had been thirty seconds. No man had ever flown as much as one second in a power-propelled machine. The boys made a careful review of all the facts known to them, and the next year, 1901, returned to Kitty Hawk, bringing with them a heavier fabric for the plane. With this they made three hundred seventy-five flights. Their longest flight was four hundred feet, made against a twenty-seven-mile-an-hour wind.

Notwithstanding the use of a heavier fabric and various changes in general design, the wings did not lift as much as the boys felt that they should; the glider was hard to manage; and they decided that the air tables they were using were not correct.

Some of these tables, supposed to show the speed and power of wind, to indicate its lifting power, and to indicate how it will act upon surfaces such as the wings of an airplane, had been prepared by Dr. Langley and published in his book on aerodynamics. The Wrights, as a result of their experiments at Kitty Hawk, believed that they could demonstrate that the figures, in many instances, were wrong. They didn't believe that they could get much further until these tables had been carefully corrected. They determined, therefore, to set them aside and to start from the ground up, building up new data that were sound.

The best way to do this, they decided, was to build a wooden box or tube into which a current of air could be turned. Then, with a small model of their plane they could observe through peepholes the direction and speed of the plane under various specific conditions.

With a few rough boards and a secondhand blower to supply a current of air, they soon had in operation *the first wind tunnel the world had ever known.* It was quite different from those handsome structures of glass and steel that we find today in our research laboratories and in some of the larger airplane factories. But crude as it was, it enabled the Wrights to observe the reactions of various small airplane models to varying air currents.

These models they flew at all angles. They tilted them at forty-five degrees, and against winds from all directions and at all speeds. They gave special attention to the shape of the wings; one of the most impor-

tant principles they were able thus to formulate was the fact that a thick rounded edge on the front of an airplane's wings is better than a thin one.

Before their experiments, the idea had been general that a knife-edge was necessary. But the Wrights discovered that the action of the air stream over and under the wings was influenced greatly by the character of this edge; the rounded thickness they found to be necessary was generally adopted and is used today.

On the Ground

In the Air

The Wrights also learned the true figures for the lift of a wing at various angles. They learned the relation between *lift* and *drift*. *Lift* is a term that means the weight that a wing will carry. *Drift* means the power required to make the plane travel at a certain rate of speed in the line of motion. The lift of a plane depends largely on the speed at which it is moved; so that, as will readily be seen, the whole question of keeping the plane in the air is dependent on speed.

Langley had worked out some interesting problems connected with

this question of lift. Sir George Cayley, long before, had attempted the solution of others. But much of the field of investigation remained unworked when the Wrights began their experiments.

We know now that a plane is held up much less by the air that is beneath it than by the suction or partial vacuum that has been created above it, over the near edge of the wing, as it moves through space. The Wrights discovered this, one of the two essential laws of flight, and thus made successful flight possible.

This suction is caused by the curved wing; as it cuts through the air it starts a current, or streamline, high over the back of the moving plane. This makes the plane rise to fill up the partially filled space that has been created above it.

In 1902 the two young men went back to Kill Devil Hill. They now had built another glider, and the progress they had made is shown in some of the things they had added to it. The plane now had a tail, or fin, placed there to steady the plane. This preserved the balance reached by warping the wings. With a rudder that was now fitted on, the plane could be guided. Far out in front of the plane was a small square of canvas, lying flat. By raising or lowering its front edge, the nose of the plane could be lowered or raised at will.

Lilienthal had balanced his gliders by shifting the weight of his body. The Wrights had followed a similar plan; but in shifting the operator's body they had warped, or bent, the trailing edge of the wings. This changed the air pressure on different parts of the wings. For by bending the trailing edge of one wing down, while the edge of the other wing was raised, the lateral or sideways balance of the plane changed at once. The tail, or fin that was now added served to keep that balance, once

it had been secured. This shifting of the trailing edge led to the development of what is known as *aileron control.* With ailerons on all planes today, it is hard to realize that their use represents such recent research and invention.

Ailerons are the hinged trailing edges of an airplane's wings. When the wind strikes the raised surface of an aileron it forces the wing down. When it strikes a lowered aileron it forces the wing up. The ailerons are so constructed that when one of them rises the one on the opposite wing is lowered, thus keeping the plane on an even keel.

Their experiments with the wind tunnel having changed many of their ideas as to the action of air currents upon various curved surfaces, the Wrights made various changes in the curved surfaces of the wings. In ten days they made no less than seven hundred flights. And these flights were by no means all of them failures. For the young men succeeded in gliding, before they were through, for forty-three seconds, which was then a world's record.

With all this success, the brothers were not satisfied. Their belief in the Lilienthal theory of gliders was changing; they determined to change to a power-propelled machine. Before they left Kitty Hawk they had begun to design an engine and propellers with which to equip their next year's plane. Airplane engines were unheard of, and the brothers were unable to find a manufacturer who was willing to undertake to build one. They had laid down six requirements for the engine they sought: It must be of extremely light weight per horsepower; it must have unusual dependability; it must be capable of operating at a constantly high speed; it must be able to operate on an unsteady framework or base, subject to great vibration; it must have a minimum con-

sumption of fuel and of oil; and all working parts must be readily accessible.

No wonder the manufacturers hesitated! Such an engine had never been heard of in all the world! But the boys were sure of what they wanted, and of what they could do. They determined to build the engine themselves. They soon were hard at work again. The little bicycle shop resounded with the sound of tools. The boys sang, and they argued, and they waited on customers, and told quaint stories of Kitty Hawk. No day was long enough for all they wanted to do!

5

The Wonderful Year of Nineteen Three

IF YOU will consult your history books, you will find there some very important years, which once learned you will never forget. There are 1492, and 1776, and 1861, for example; you know what happened in every one of them.

But 1903 was a great year too, though history doesn't give it a great deal of space as yet. It was great because in that year man first learned to fly.

There had been Dr. Langley, with the *aerodromes* of which we have just read; and here were Orville and Wilbur Wright, ready to attempt this thing that no man had ever before done.

The winter had been a hard one for the boys, presenting many new

problems to be solved. One of these was the problem of propellers. With the engine well under way, a mechanism to give it effect must be produced. Should they use paddles, a screw propeller, or a longer propeller blade? At what speed should the blades revolve? How many such blades should there be? And most serious of all, what shape should they take? The Wrights could find but few data upon which to build. Pettigrew, to be sure, in 1867 had made various studies of the question, and Langley had had to face it. But aside from these, practically nothing had been done. Most investigators had believed that the future of flying lay in the glider type of plane, where engine and propellers were not required.

The boys finally designed and built two pairs of propellers, not greatly different from the propeller blades we use today. By scientific methods, they had carefully worked out the shape of the blades, and they had determined that the propellers should run at the rate of about thirteen hundred revolutions per minute. The two pairs were to turn in opposite directions—one pair to the right and the other to the left.

At last the time came for them to go back to Kill Devil Hill. Autumn was here again, and with it, flying weather. The great event of 1903 was about to be staged. A new plane had been built. The engine had been built. The boys put out for Kitty Hawk.

They put in several hard weeks among the lonely sand dunes, for the whole plane had to be put together and tuned up. The engine, too, had to be assembled and tested. The plane had to be much heavier and stronger than the gliders they had been practicing with; so they built a frame of steel tubing. This failed to stand the strain. Then they constructed a framework of gaspipe. It failed them, too. One of the broth-

ers had to go back to Dayton and build a framework of solid steel.

Another source of trouble was the device for starting the plane. It seems strange now when we realize that such a device for several years afterwards was used to start airplanes. It consisted of a derrick and a short track, down which the plane could be propelled by the falling of a weight. This had to be built and tried out a score of times. The engine was not powerful enough to start the plane without help.

A hundred other problems had to be solved and adjustments made; it was not until December that, one cold and blustery day, one of the lifeguards at Kitty Hawk came running down across the sand dunes:

"They done it!" he cried, heedless of his grammar. "Blamed if they ain't flew!"

Orville was the first to ride. He flew a hundred five feet. Then various efforts resulted at last in a distance of a hundred seventy-five feet, the plane rising to a height of fourteen feet. The same day, cloudy, and with a wintry wind, the machine covered a distance of over an eighth of a mile—a whole minute of breathless wonder and excitement! For they had flown 852 feet, at the rate of thirty-one miles an hour; after centuries of waiting it had been finally demonstrated that man can actually fly in a power-driven machine.

It didn't seem very important to the world. The boys telegraphed their sister, and the old Bishop drove down street to stop at a newspaper office. "My boys flew," he said. "Here's a little piece about it that I'd like to have you put in the paper."

The newspaper man looked it over. "Fifty-nine seconds, eh?" he said. "If it had been fifty-nine minutes it might be worth while." But the

newspaper man was wrong. For a world-stirring event had occurred—one that has changed the whole course of human affairs.

The two young men quickly came home. They had dismantled the plane; and in their busy minds a hundred changes were already taking shape. The little shop rang with the sound of tools, and again the brothers were singing, arguing, and planning as of old. Presently they got the use of a vacant pasture just outside of town, where they could make practice flights. Now and then some unsuspecting traveler passing along

Tickets of Admission to the Fort Myer Trials—Note Orville Wright's Signature at Lower Left Hand Corner

the country road would hear a sudden roar and watch with gaping wonder the strange machine above his head.

The Wrights were very persistent. In 1904 and 1905 they made one hundred fifty flights. One of their difficulties had been that until now they could not make a short turn without going into a tail spin. This they now learned to avoid; they were able to make a flight around the pasture of twenty-four and a half miles.

Feeling that now the plane was a practicable affair, they began to seek support from the various governments. At Washington they were told curtly that flying was not practical and that the government was not interested. In France and Great Britain the attitude was different. France sent a representative to see them; he was soon followed by a man from the British government. Finally, the American government, slow to admit that flying was a practical, accomplished fact, relented, and offered a prize of $25,000 for a successful flight. The plane should carry two men, stay in the air an hour, and attain a speed of forty miles per hour. The contest was held at Fort Myer in July, 1908; it was attended by President Taft and a throng of notable people.

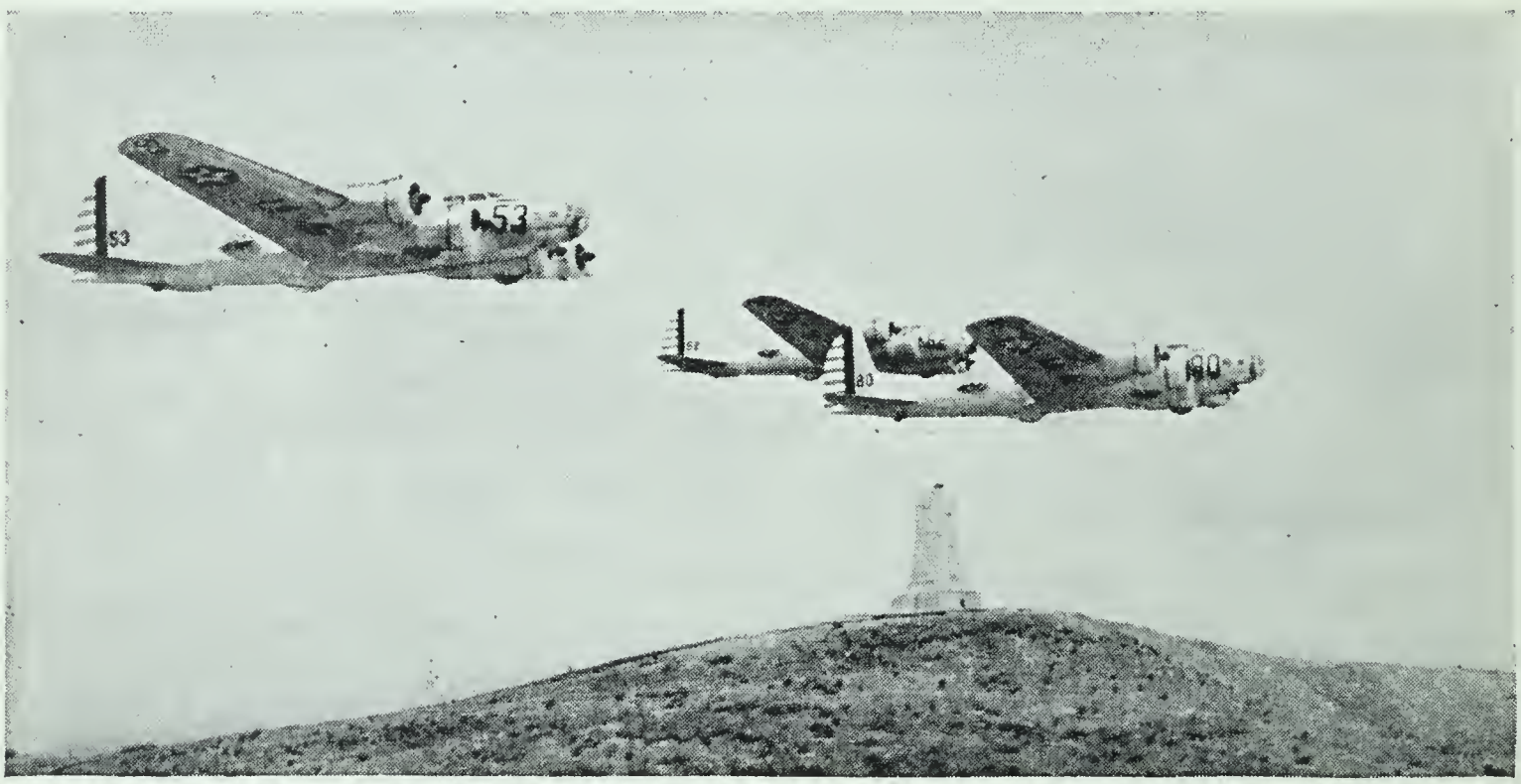
The Wrights were the most unassuming of men and paid but little attention to the noted people who were there to look on. Orville was to make the flight. When he was ready, he quietly tied a string around his cap, took off his detachable cuffs, took his place in the plane, said: "Let 'er go!" In an hour the prize was won!

The brothers went to Europe about this time, making many exhibition flights. Kings were glad to take them by the hand; emperors sought them out. People showered them with attention; but in the midst of the world's acclaim, Wilbur died.

A few years ago, on the twenty-fifth anniversary of the historic first flight, a monument was dedicated to the Wrights at Kill Devil Hill, on the bleak dunes of sand. Orville was there, his hair now gray. Not a word did he speak through all the impressive ceremonies. Across the dunes the wind blew free. Out over the ocean the eagles used to swoop and rise while he and Wilbur watched their flight. As he looked at the graceful granite shaft he seemed again to hear his father's voice as, with his children gathered round him, he had read to them in those far-off years:

> They shall mount up with wings as eagles;
> they shall run and not be weary . . .

Weary, did it say? Overhead a dozen great planes circled and rose, and circled again as he slowly turned away.



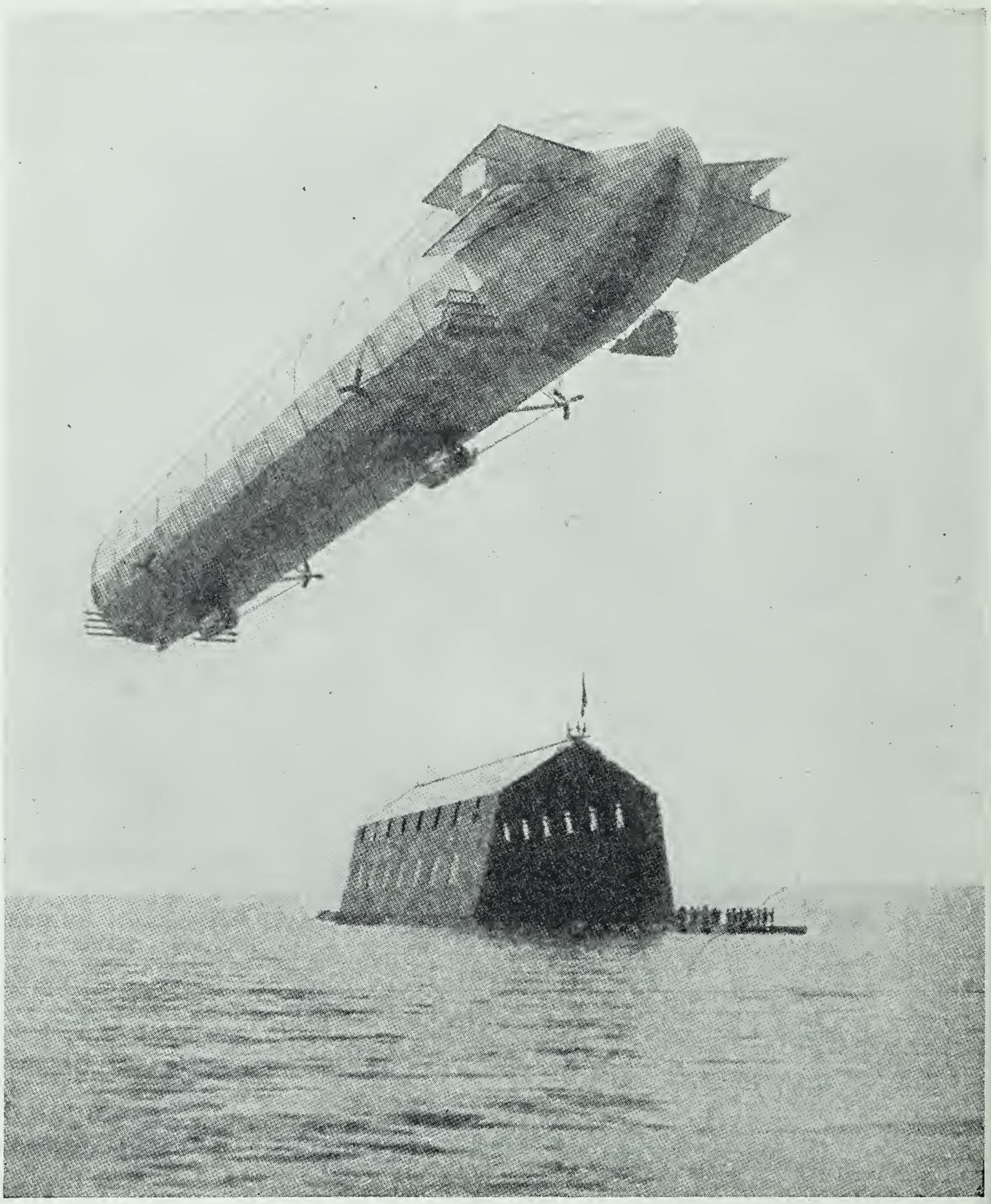
Wright Memorial, Kitty Hawk

6

The Daring of Santos-Dumont

THIS chapter is to be wholly a tale of bold adventure. Did you ever hear about Brazil? I mean the country in South America where some rivers are so broad that you can't see from one shore to another, where they raise rubber and coffee, and where in the dense and far-reaching forests great serpents lurk and wild beasts lie in wait on the limbs of mighty trees, ready to spring on the unsuspecting traveler? They say that its rivers are Rivers of Doubt, and that savage Indians and wild cattle roam its plains.

I have met a traveler, too, who says that not all of Brazil is like that. In part, it is a lovely land, he said, with beautiful cities that nestle under glorious mountains, whose feet are bathed by the warm waters of broad



The First Zeppelin over Lake Constance

bays. He said, too, that the people are warm-hearted and impulsive, and that they love romance, adventure, and courtesy.

Alberto Santos-Dumont was like that. He was the son of a Brazilian coffee planter. Loving adventure, he took ship for France and sailed away, eager to learn to fly. Soon after he reached Paris, he asked a balloonist what he would charge to take him for a trip in the air. "Twelve hundred francs," the aeronaut said. "Not at all," said Alberto. "I'll build a balloon myself."

So he did. In fact the dapper little man built many of them, and the French people admired and praised him very much. He wasn't always successful with his balloons, though he had many strange experiences with them. Once, in a great storm at Nice, in trying to descend, he found that the air currents *were all going up!* He threw out ballast and let out gas, but still up he went. He rose ten thousand feet. He couldn't feel the storm, because he was being carried along with it; but when he finally was able to descend to lower altitudes, he could see the wind lashing the trees and the sea dashing against the rocks. Finally he came down so low that the balloon was dragged through tree tops and over rocks at a terrific rate. With bleeding face and hands and torn clothes, unable to save himself, he finally fell out of the basket; then the doctors sewed him up and put him to bed.

Such experiences didn't bother him greatly. Before long he was up and at it again. He next built, in striking contrast with the large zeppelins that the Germans were building at about the same time, a small airship, eighty-two feet long. It was equipped with a gasoline engine, rudder, and propellers, and the next year he sailed right over the Champs Élysées in Paris itself. The French people went wild with delight!

Then, in 1901, he won a prize of a hundred thousand francs for circling the Eiffel Tower. The conditions of the contest were that the air-

Santos-Dumont Rounding the Eiffel Tower

ship should rise at the suburb of St. Cloud, fly to the tower, circle it, and return to St. Cloud, all within the space of half an hour.

Practically no one had ever been able to fly in a circle; but nothing daunted Santos-Dumont. As he passed the tower, with a sudden move-

ment of the rudder he turned within a radius of fifty meters, swept round the tower, and started on his return journey against heavy head winds. These, with engine trouble, slowed him down badly. As he passed over the aerodrome at the end of the journey, he called down to his assistants: "Have I won?" "Yes," they cried back, "you still have twenty-nine seconds to the good."

To realize all that this closely earned victory meant to him, it must be understood that he had already tried to win it twice before. On the first attempt, as he approached his starting point, the motor stopped, and the whole structure, with the operator himself, was precipitated into a chestnut tree. The next time the effort resulted in the destruction of his craft, due to a defective valve. It was in his sixth balloon that he at last succeeded.

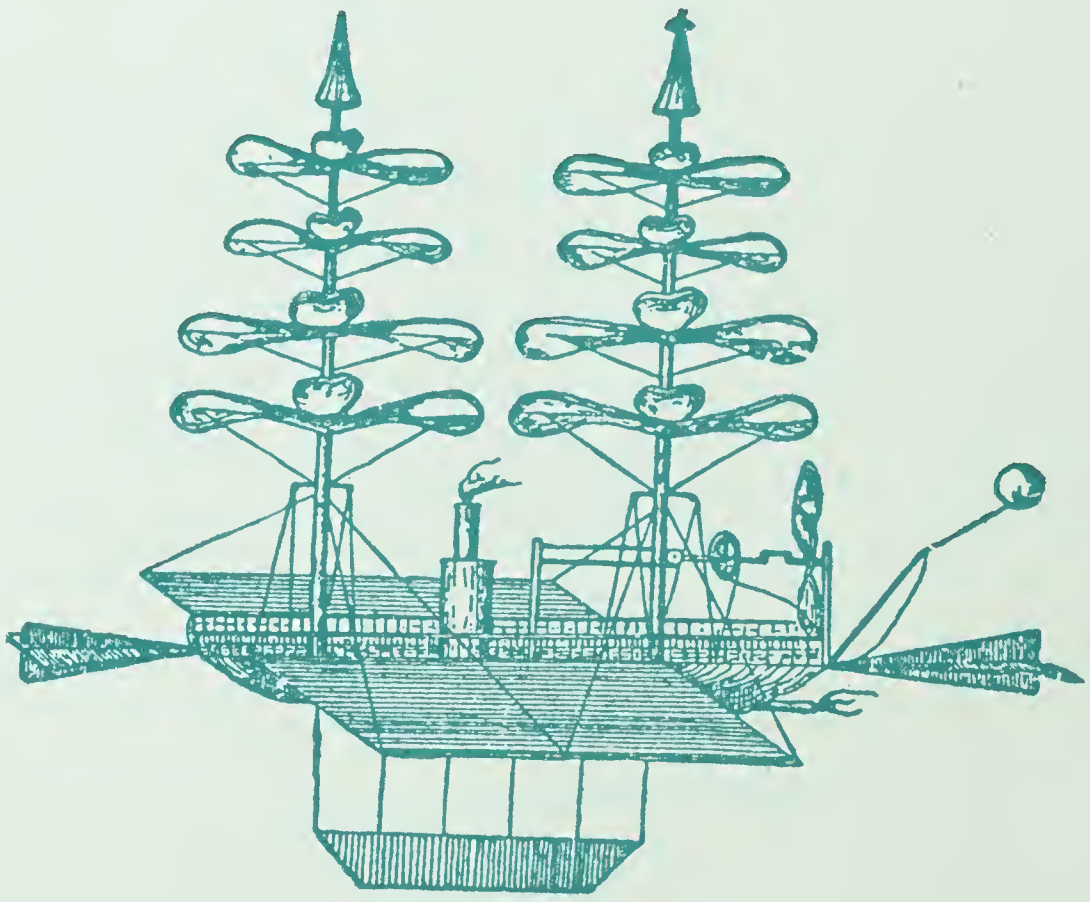
Oh, but the French were proud of him—of his skill and of his nerve and grit!

"*Vive le Santos-Dumont!*" they cried, "*Vive le Santos-Dumont!*" And they carried him on their shoulders, and kissed him on both cheeks, and cried, and laughed, and patted him on the back, and he was the idol of their warm and excitable hearts. I like these warm-hearted folks. They give you something to remember things by.

Santos-Dumont, who had been the first man ever to use a combustion engine on an airship, saw the trend toward heavier-than-air machines. But his name is best known in connection with balloon and airship experimentation. One of the little Brazilian's most daring feats was with the little *Demoiselle*. Rising at 2:00 A.M., when there was but little traffic on the streets, he drove down the Champs Élysées and up to his own door in the little airplane. Here he left the plane in the

footman's charge and tripped lightly upstairs for a morning cup of coffee, returning lightly in a few moments to step into the plane, and away again.

When the heavier-than-air machines came into use and flying settled down into a steadier business, with less glamour and glow of adventure, Santos-Dumont, the gay, brave, and dapper little adventurer, dropped out of public sight. A few years ago I picked up a newspaper. "Died," it said, "aged fifty-nine, Alberto Santos-Dumont." Back in his native Brazil, under the glorious mountains whose feet are lapped by warm waters, I wonder if he sometimes dreamed of the gay city and its graceful Eiffel Tower, and of the excited crowds that bore him on their shoulders and cried *Vive le Santos-Dumont?*



7

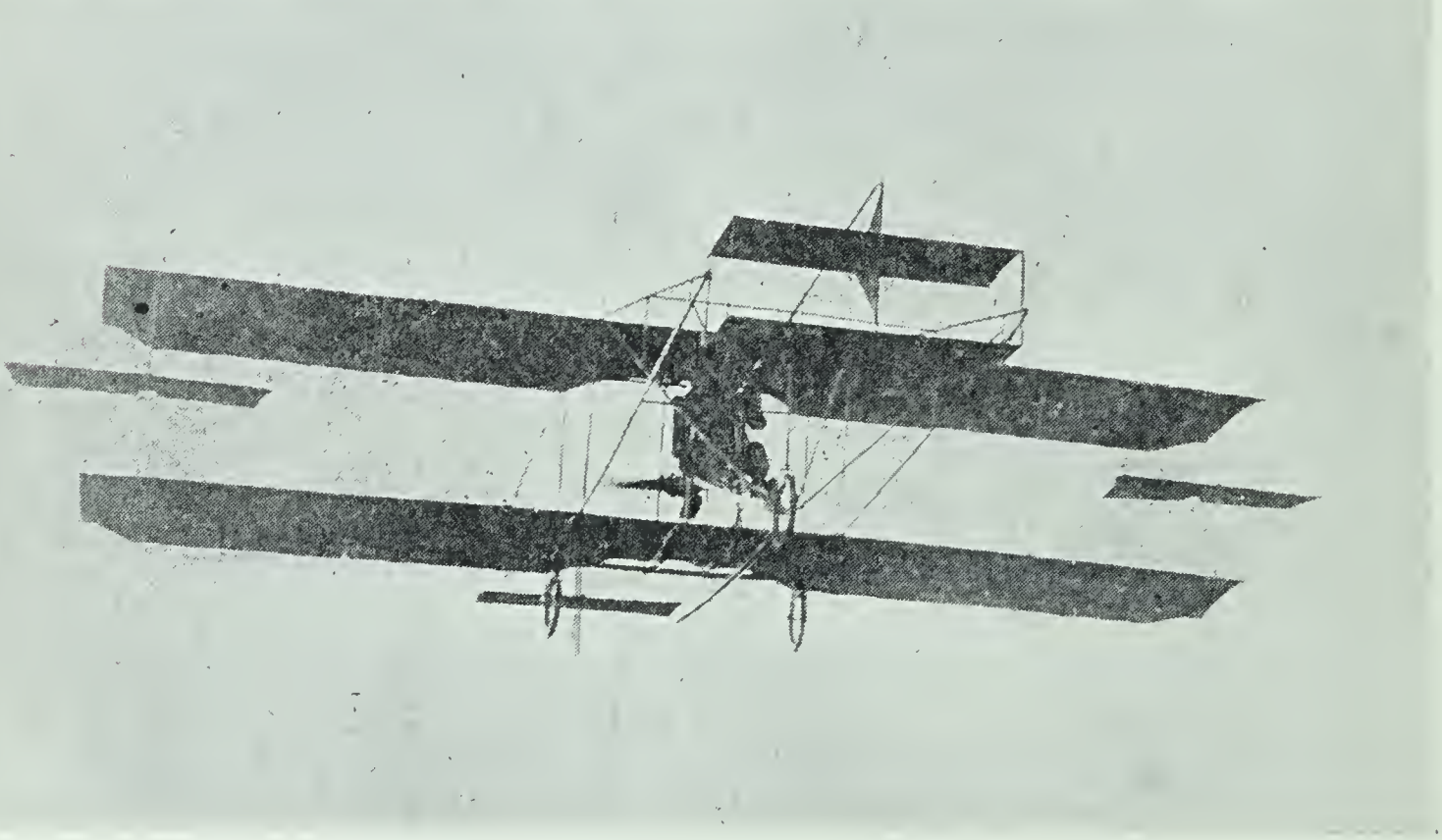
Ten Active Years

ABOUT the time that Santos-Dumont was circling the Eiffel Tower, a number of brave hearts were ready to test their wings against the air; by 1908 considerable activity had set in. The Wrights had set the pace by then; following in their footsteps were such men as Farman, Voisin, Bleriot, and Grahame-White—you could name a score of them who dared, and daring, accomplished great things.

In 1909, Bleriot, the father of French aviation, flew across the English Channel, Barraques to Dover, in a monoplane. He made the journey in thirty-seven and one-half minutes and won a thousand pounds. About this time the discussion over the relative merits of biplane and monoplane design was at its height. Bleriot's machine was admittedly a considerable step in advance in airplane design.

In that same year the first air meet in history was held at Rheims. Here young Glenn Curtiss, who had been a bicycle racer, won the James Gordon Bennett cup by flying twenty kilometers in sixteen minutes. It was in a biplane, built of American white spruce, braced with piano wire, the elevator and rudder supports being made fast to bamboo stays. It carried a forty-horsepower motor that weighed two hundred pounds. Rather frail and undependable—we would not permit such a machine in the air today. The test flights were very short, and could be made only in the still air of a quiet summer sunset or sunrise. In the same year Wilbur Wright, taking part in the Hendrik Hudson Tercentenary in New York City, amazed and thrilled the assembled crowds by flying from Governors Island, in the harbor, to Grant's Tomb, twelve miles up the Hudson, and back to the starting point.

The next year, 1910, saw still further activity. Claude Grahame-



Glenn Curtiss in Flight from Albany to New York City

White and Paulhan tried for a prize of £10,000 offered by the *London Daily Mail* for the first plane to make a flight from London to Manchester, a distance of 183 miles. A Frenchman named Fabre flew the first seaplane that had ever been flown. And Glenn Curtiss flew from Albany to New York City, stopping once on the way, and winning a prize of $10,000 offered by the *New York World*.

Grahame-White, who had nearly won the prize which Paulhan took for the London to Manchester flight, now flew from New York to Washington, landed in the street before the White House, paid his respects to the President, who had seen his first airplane barely two years before, and returning to the plane, took off again from the center of the street.

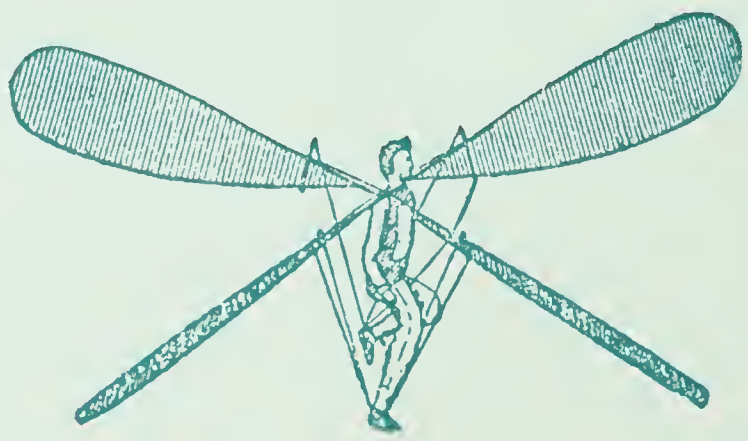
It was in this same exciting year that Santos-Dumont had flown his

A Bicycle Built for One—A Modern Experiment in Man Flight

dainty little *Demoiselle* down the Paris streets, and left it, much as one might leave a mettlesome horse, with the servants at the door.

It was all very gay and cheerful, and most of it quite lacking in anything like practical use; for there were almost no airports, few landing fields, few pilots, and fewer passengers, even if the planes had been large enough and powerful enough to carry them. There were no commercial lines such as we now have, no air mail, no air express. Made of bamboo, muslin, and varnished sateen, the planes carried small engines that were imperfectly designed and of uncertain performance. It was not until the outbreak of the World War that aviation entered its next phase. When the war broke out, the airplane and the airship were found to fall within the military needs of the day; one of the results was that more advance was made in the development of aircraft in the four years from 1914 to 1918 than had been made in forty years of peace.

The war over, hundreds of airplanes were turned into peaceful channels, and great strides were made toward the development of peaceful uses for them. Aircraft and airways were now to become a part of the great transportation system of civilized society.



8

Over Land and Sea

IT WILL therefore be seen that by the year 1920 men had gone through several distinct phases of flying progress. There was, first, that ancient period when the gods were thought to look with jealousy on any effort man might make to travel through the air. Then came the period when various foolish experiments were tried with wings, robes, magnets, and hollow copper balls. After that came the age of balloons, when men rose and soared, the plaything of the winds, coming down, no one could tell when or where.

Then came the heavier-than-air machines, with Lilienthal, Langley, the Wrights, Bleriot, Voisin, Farman and Grahame-White, when daring men, eager to show their skill or to win a prize, flew a few miles

and were the admired heroes of thousands. It was the World War which brought planes to a point of usefulness, if indeed war can ever be called useful. At least, it showed mankind that airplanes could be something more than playthings; it put them to a use so deadly that the nations vied with one another to perfect them. In four years, the advance made in the art of flying was so astonishing that the world became air-minded to a degree never before dreamed of.

After the War? Men hardly knew what to do next. So they flew in daring tail spins and nose dives, flew races, and showed off generally,

Over the Mountains

waiting for the time when flight by air might be made a useful art.

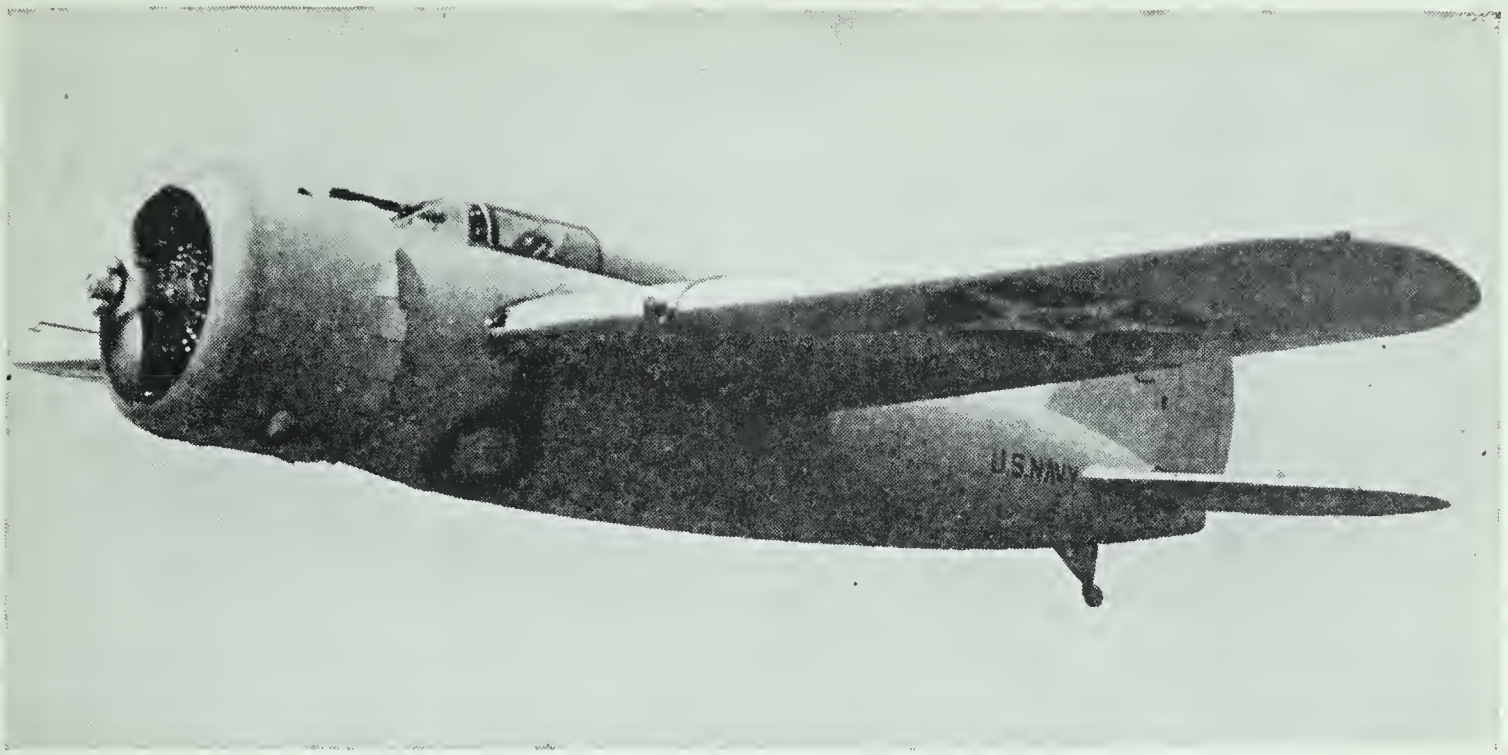
Finally came the days of orderly usefulness such as we know today, when fast and willing planes succor the sick, find the lost, seek out the frozen poles, and each day carry out a regular and uneventful routine of carrying people and the mails between our cities and across the seas.

Travel by air has thus been of real use to mankind only for the last twenty years; much of the credit for making it serve us belongs to men still living. The Wrights flew in 1903, the first seaplane was built in 1905, the first monoplane in 1908, and the English Channel was crossed

Pan American Clipper Starting on a South American Flight

in 1909. A table of these dates forms a most interesting story of how rapidly flying has grown. Airplanes at the beginning of the World War were built of white spruce and rods of bamboo, strung with piano wire and covered with muslin, sateen, or varnished silk. They carried engines of forty or fifty horsepower, and could fly about forty miles an hour. By the end of the War the engines ran up to a hundred horsepower, the speed up to a hundred miles an hour, and the planes were large enough to carry one or two passengers. But the cruising range, that is the distance a plane might be expected to fly without refueling or reconditioning, was small. Men were trying hard to enlarge this range, and one of the first things to do was to increase the power of the engines with which the planes were equipped. The United States in her war effort, designed and built what were known as the Liberty engines, turning out 15,572 of them in a single year, and producing an engine which at that time was the latest advance in design. France, too, had made great strides in engine design; planes were larger, and while but little metal was used as yet, construction was now much more dependable and able to stand the shocks and strains to which a plane is subject.

With the improvement in construction came an increase in fuel-carrying capacity, without which no long flights could be undertaken; and five years after the Wrights had broken all records by staying in the air twenty-four and one-half hours, there was talk of ocean flights of two thousand miles. This conquest of the North Atlantic by air was a most fascinating thing to the adventurous men who were now flying. Walter Wellman started it by taking off from Atlantic City, in 1910, in the *America*. It was a small airship with pontoons trailing below it



Modern Naval Plane

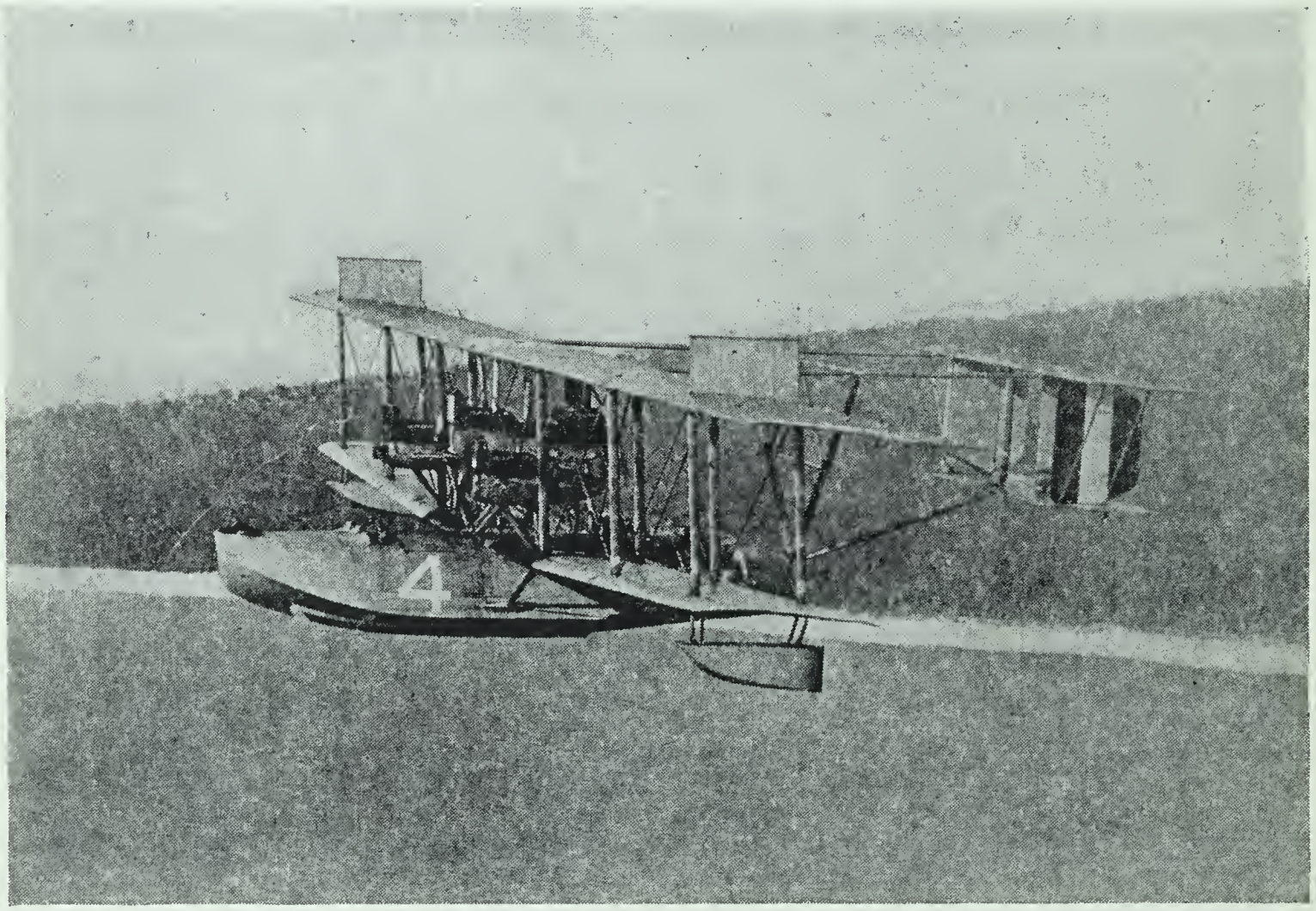
above the water, to insure steady flight. The *America* didn't get far before it had to descend. In 1913, Lord Northcliffe, the publisher of the *London Daily Mail*, offered a prize of £10,000 to the first Englishman who would cross the Atlantic by air. The offer stood open for a long while. In the meanwhile, during the World War, Glenn Curtiss had designed a flying boat to cross the sea, and the United States government had built four of them. They were known as the Navy-Curtiss, or "NC," boats.

Three of these NC boats, the NC-1, NC-3, and NC-4, started across the Atlantic in May, 1919, the NC-4 completing the trip from Newfoundland to Lisbon, in Portugal. The NC-4 was the only one of the three NC boats that completed the trip, which started from Trepassy, Newfoundland. The route called for a stop at the Azores.

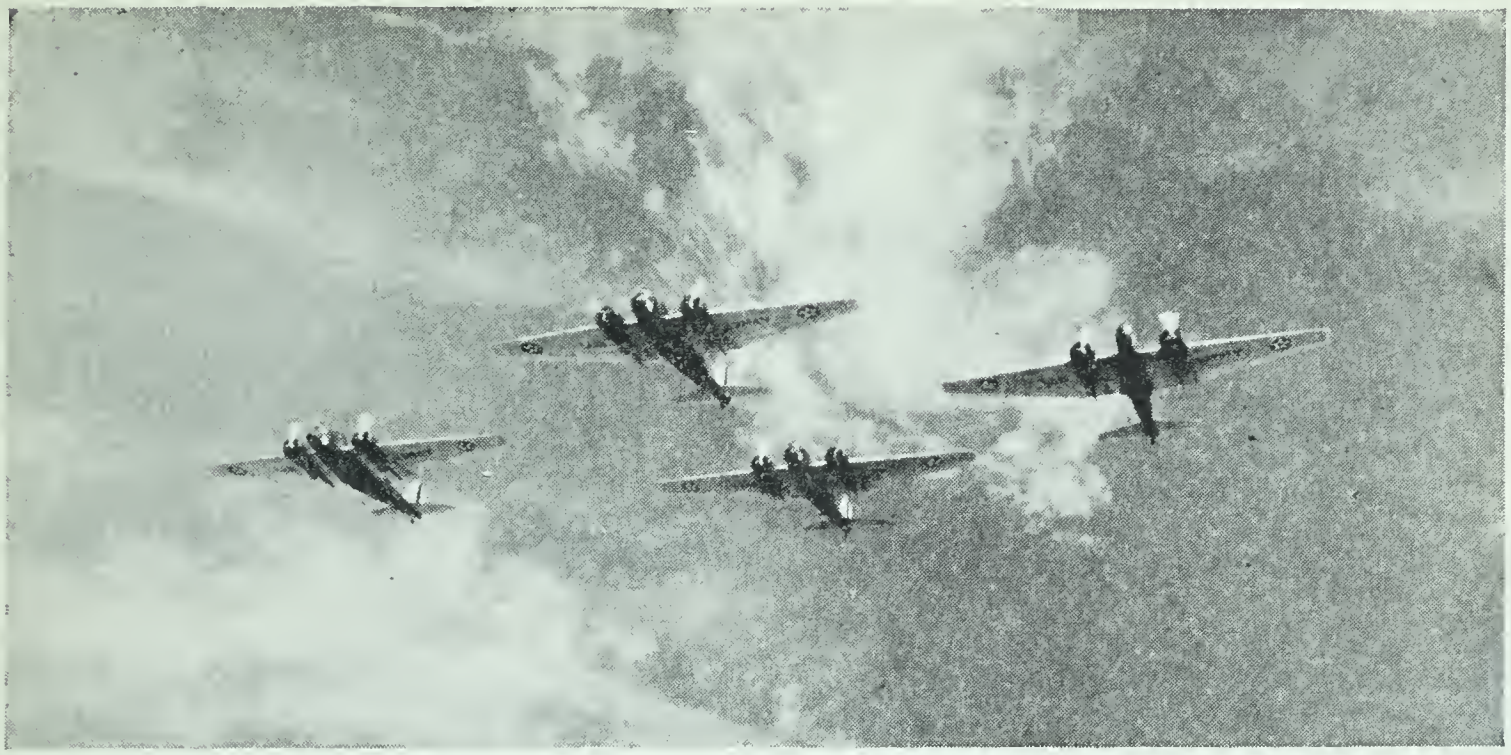
Meanwhile, English aviators were quite on edge about that prize of £10,000. In an attempt to win it, Captain J. Alcock and Lieut. A. Whit-

ten-Brown flew from St. John's, Newfoundland, about the same time the NC boats were on their way. Their ship plunged quickly into banks of fog and cloud, rose to the height of 11,000 feet, flew across the Atlantic, sighted the west coast of Ireland, stuck the nose of their plane straight into an Irish bog, and thus rather ignominiously completed *the first nonstop flight across the Atlantic*. They were in the air about sixteen hours.

H. G. Hawker and his companion, Commander K. Mackenzie Grieve, took off from St. John's, Newfoundland, in a twin-motored Sopwith biplane, the *Atlantic*, just after the NC-4 had reached the Azores, in competition with Alcock and Brown for the £10,000 Northcliffe prize.



NC-4



In Flight Formation

At the end of 1400 miles the plane dropped into the sea. Both men were miraculously saved.

We do much better now. In 1937, Merrill and Lambie flew from New York to Croydon, near London, in twenty-one hours, bearing photographs of the *Hindenburg* disaster, and back again almost immediately to New York with photographs of King George VI's coronation.

To go back again to 1919, three weeks after Alcock and Brown had won the £10,000, the R-34, a British airship, flew across from Scotland to Long Island and back again.

Then interest seemed to die down for several years, until Raymond Orteig, a New York merchant, offered a $25,000 prize for the first nonstop flight from New York to Paris. This offer came to the attention of a young air-mail pilot who was at that time flying the mail between St. Louis and Chicago, and who thought he would like to make the attempt. His name was Lindbergh.

Charles A. Lindbergh, at the time the Wright brothers were taking off from Kill Devil Hill, was a small boy who had never even seen an airplane. In fact he was a full-grown man before he had been near enough to one to put his hands on it. But he caught the flying fever quickly after that. Within a week he had ridden in one, and, having made up his mind to study the art of flying, turned his back on the engineering school at the University of Wisconsin, where he was a student, and started for a flying school about which he had heard. The

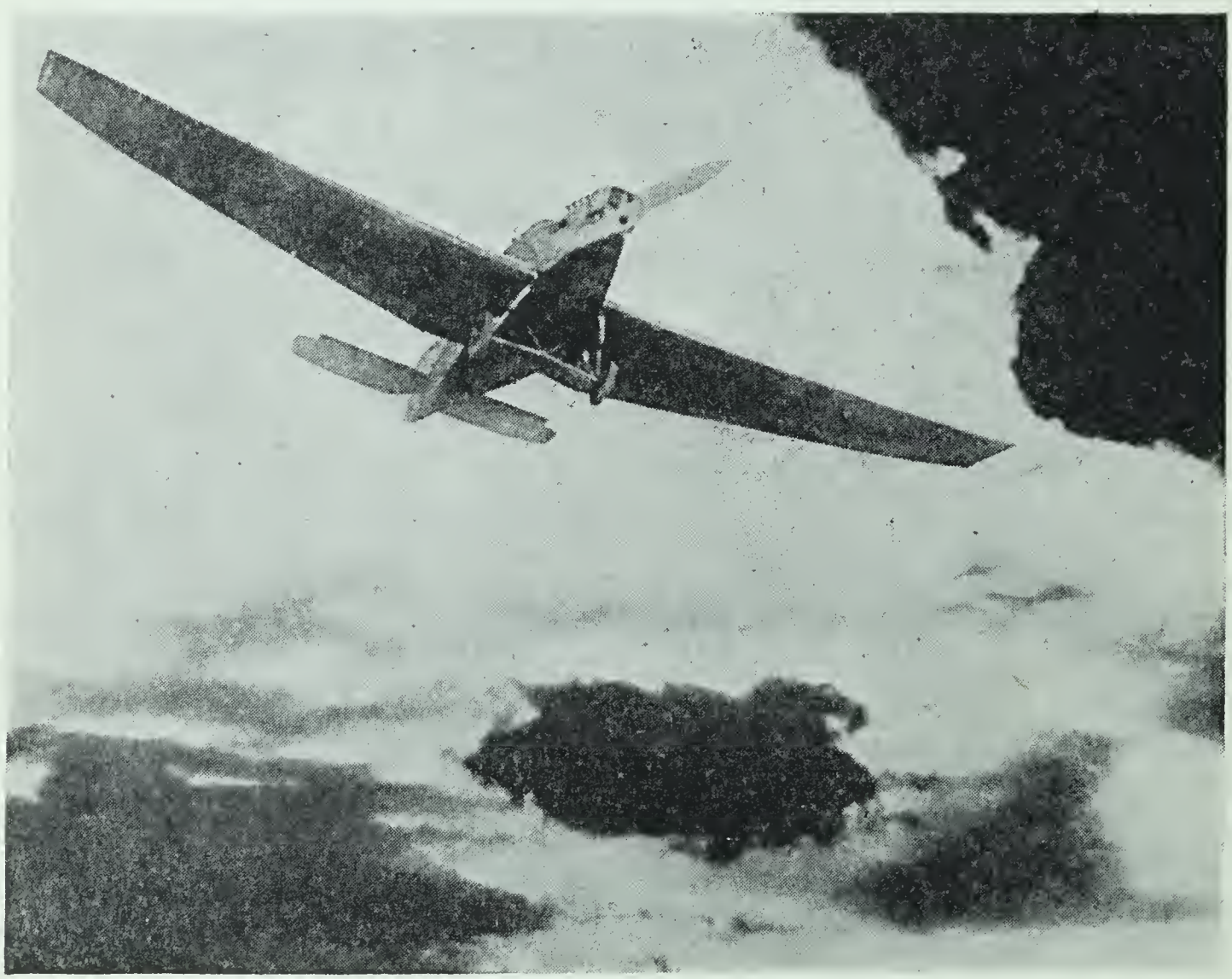
school was located at Lincoln, Nebraska. At that time it wasn't a large school. It is said that he was the only student and his instructor was the only teacher. But he was an apt pupil; after eight hours of instruction, he was off on a barnstorming expedition with an experienced pilot, who allowed him to try parachute drops and various other daring stunts.

He kept up these exhibits until the season closed, and when spring opened, started south. Here he bought an old army plane and set out

Amelia Earhart

across the southern states for Texas, although up to that time he had never flown alone. He met with a hundred strange experiences. He passed through sudden thunderstorms, landed in boulder-strewn fields, went rocketing into hidden ditches and unavoidable swamps, slept under the wings of his plane, and finally left Texas to fly north to Lincoln, to the old flying school.

On March 24, 1924, he enlisted as a cadet in the air service of the United States Army, and reported for duty at Kelly Field, in Texas, being commissioned at Brooks Field, near San Antonio, as a second lieutenant in the flying service. Later he joined the Missouri National

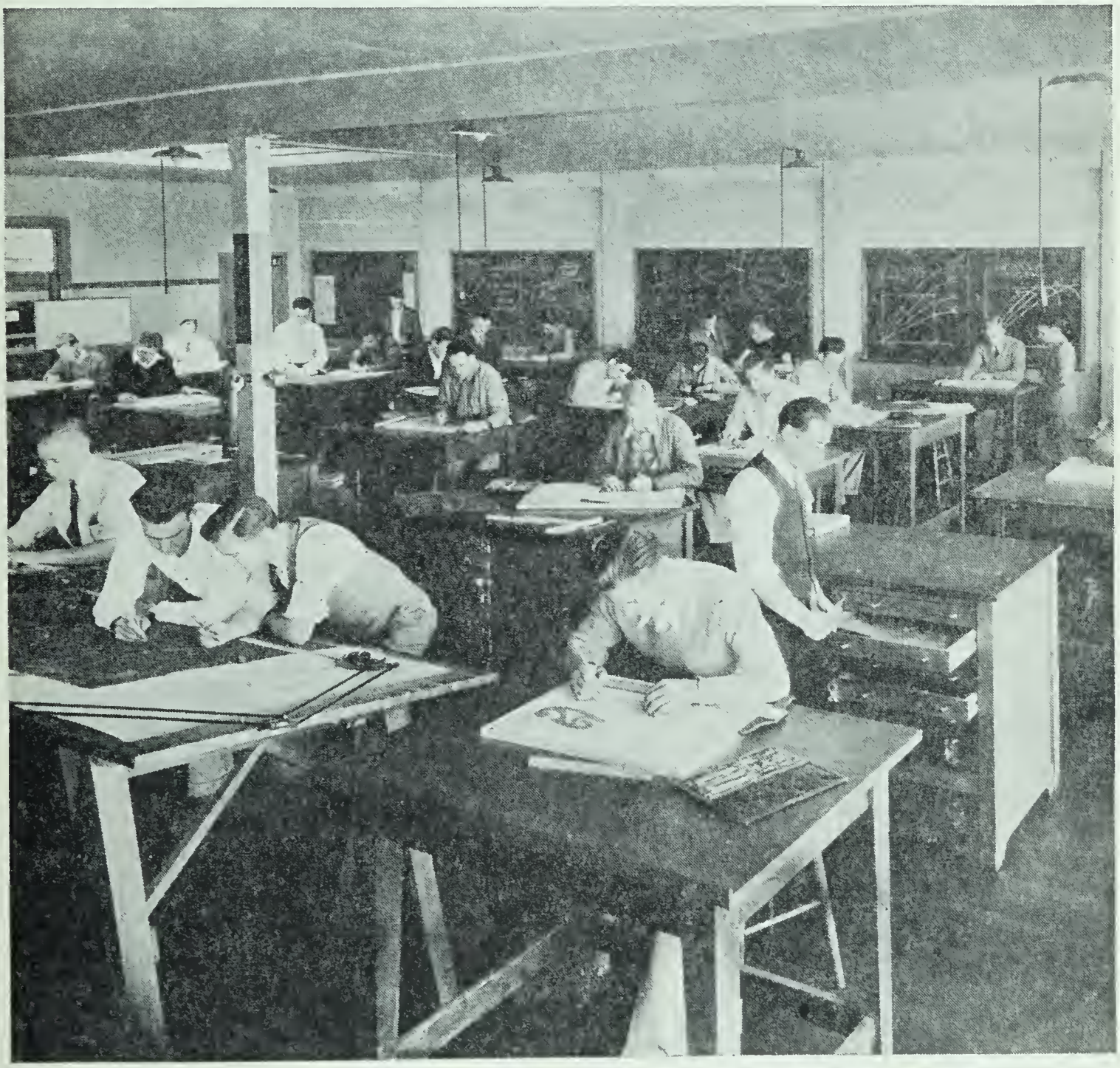


The Bremen—First Transatlantic Airplane Flight Westward—Koehl, von Huenefeld, and Fitzmaurice, April, 1928

Guard and was commissioned as captain in the Officers' Reserve Corps.

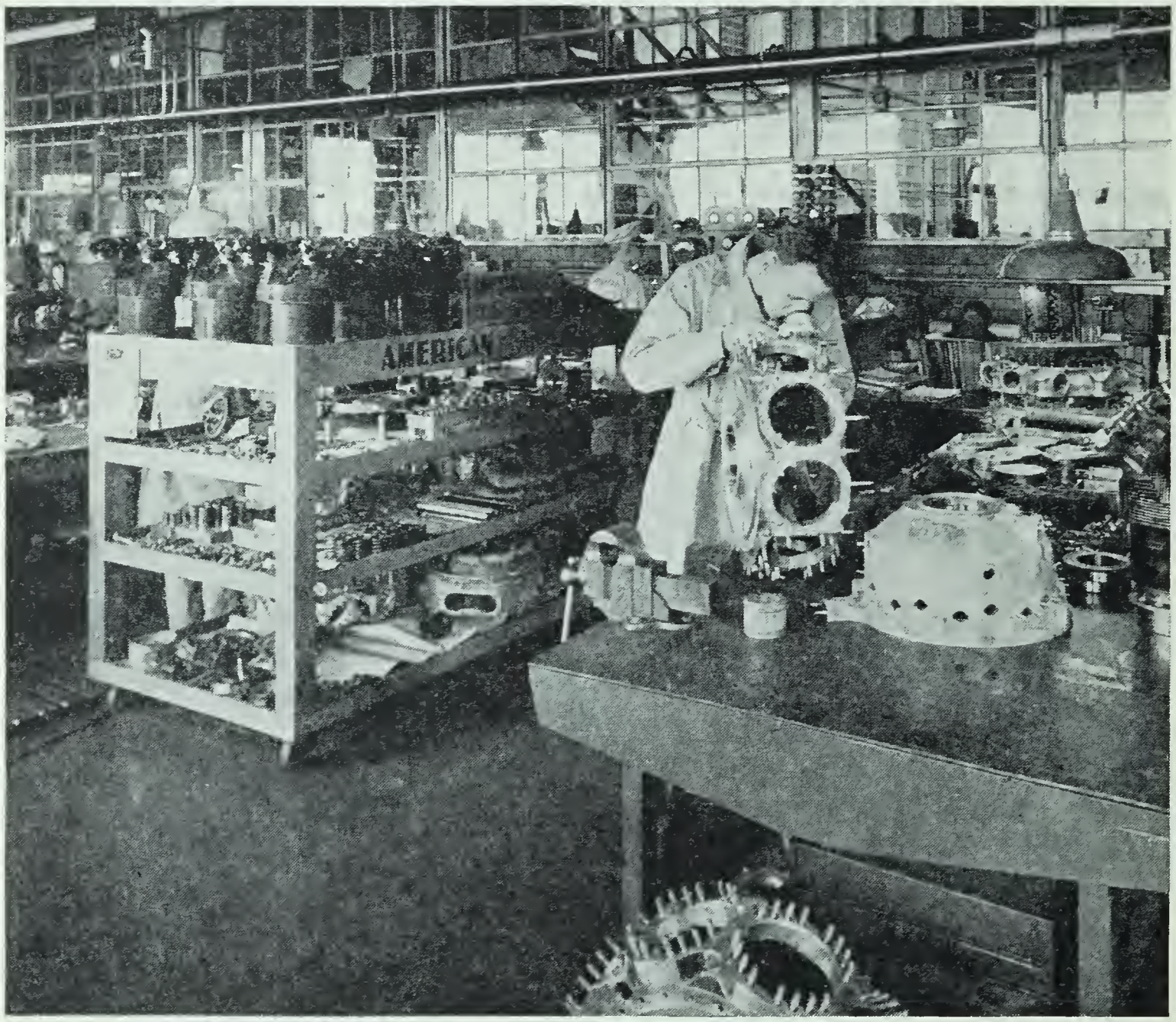
Meantime, he had become an air-mail pilot; here he was able to put to practical use some of the things he had learned in his barnstorming experience. The route was unlighted. The pilots had to fly through fog, rain, darkness, and driving snow, and frequently had to "bail out."

At this time it must be remembered that the art of flying still had a long way to go. Not much metal if any was used in the construction



Drafting Room, Airplane Factory

of planes. Most planes were only large enough to carry the pilot and one or two mail bags. Nor was much flying being done. Aside from two or three lines of air mail, there were no regular commercial flying routes. When people did fly, it was usually to go up a few minutes for

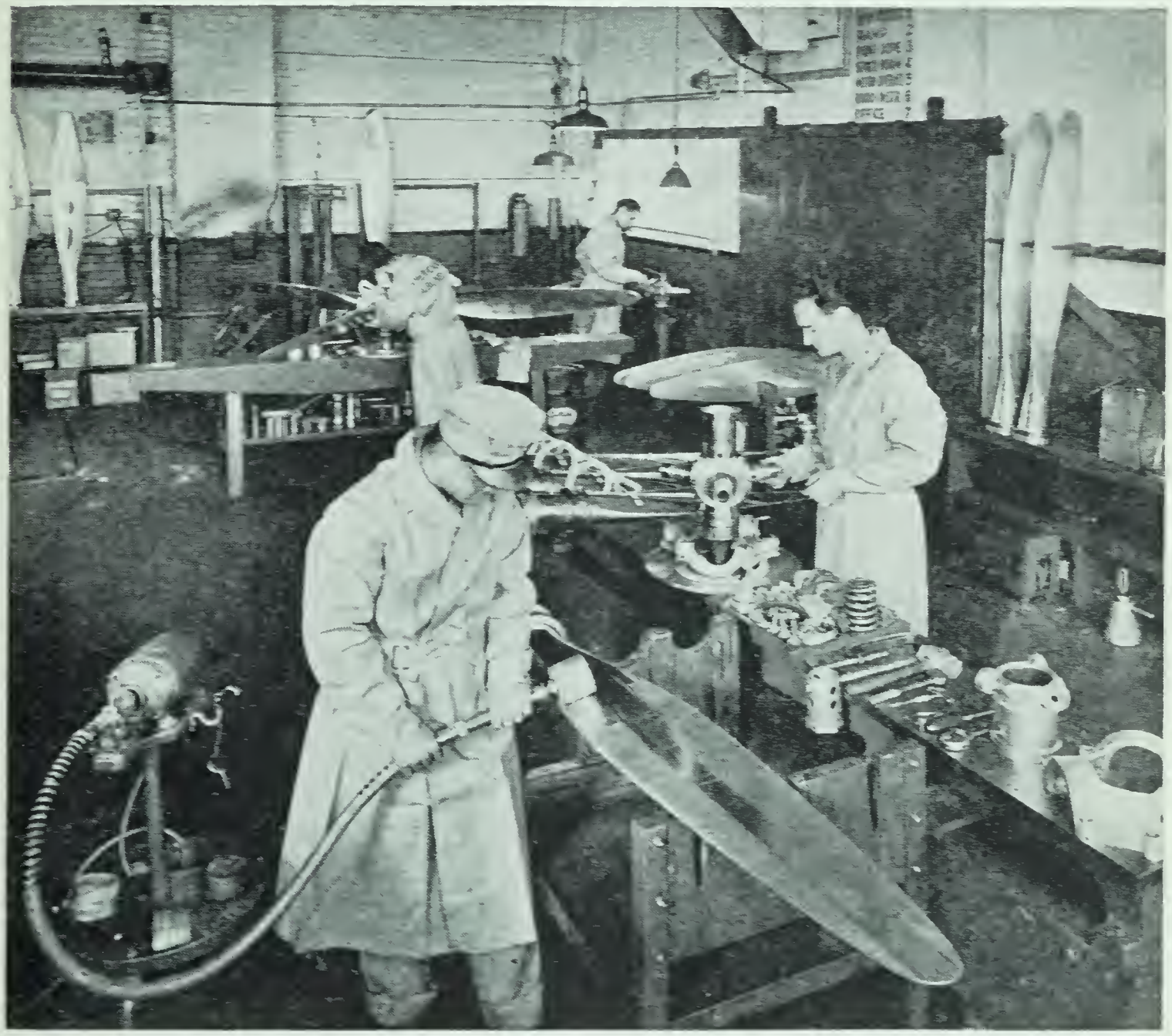


Machine Shop, Airplane Factory

a turn or two round the aviation field and then back to the place from which they started. For this purpose, fliers, many of them with experience in the World War, bought old planes which the army was selling, established themselves somewhere in a meadow or stubble field,

picked up a few passengers with courage enough to risk a short ride, and did hair-raising tricks in the air.

These barnstormers also followed street carnivals and circuses, looped the loop, turned tail spins, went into nose dives, and walked out on the



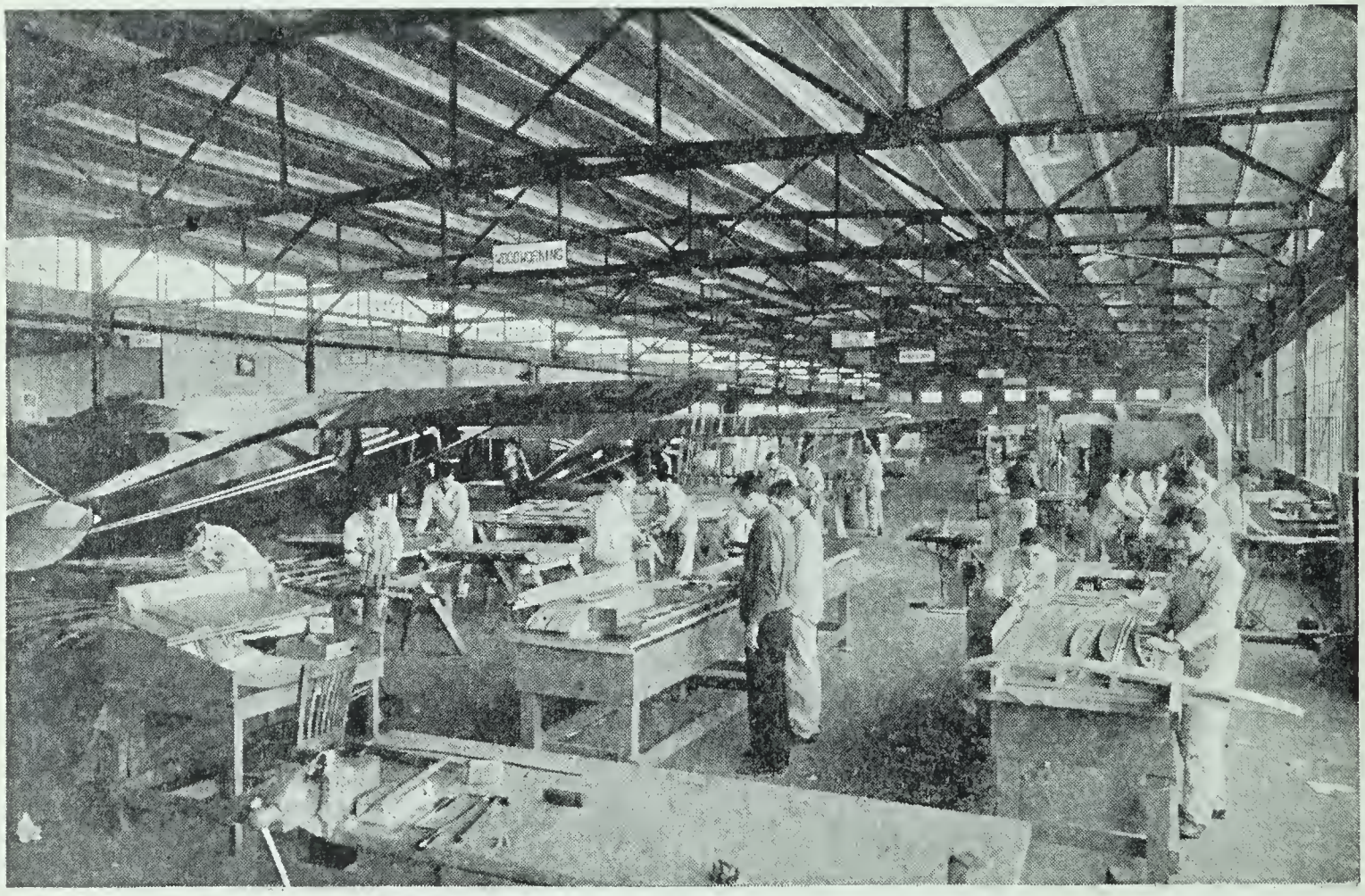
Smoothing the Surfaces of Propeller Blades

wings, attracting great crowds of the curious. Men with little or no training tried for altitude in the teeth of an eighty-mile gale; as early as the year 1915 an aviator had undertaken to fly through Machinery Hall at the San Francisco Exposition, with the building crowded with

people. Another tried dodging the skyscrapers in lower New York.

Lindbergh had been through all this; while making his regular air-mail trips and battling storms, fogs, and broken-down engines, it is possible that he chafed a bit at the lack of something more exciting. At any rate, he saw the Orteig offer and began to think seriously about trying for it.

In 1926 he found a group of men in St. Louis who were willing to supply the money to build the plane and to take care of the expenses of the trip. It was clear to Lindbergh that the success of the flight would depend largely on the care taken in its preparation. He had seen this in the difference between the failures of various flights such as that of Hawker and Grieve and the success of the NC-4. There must be

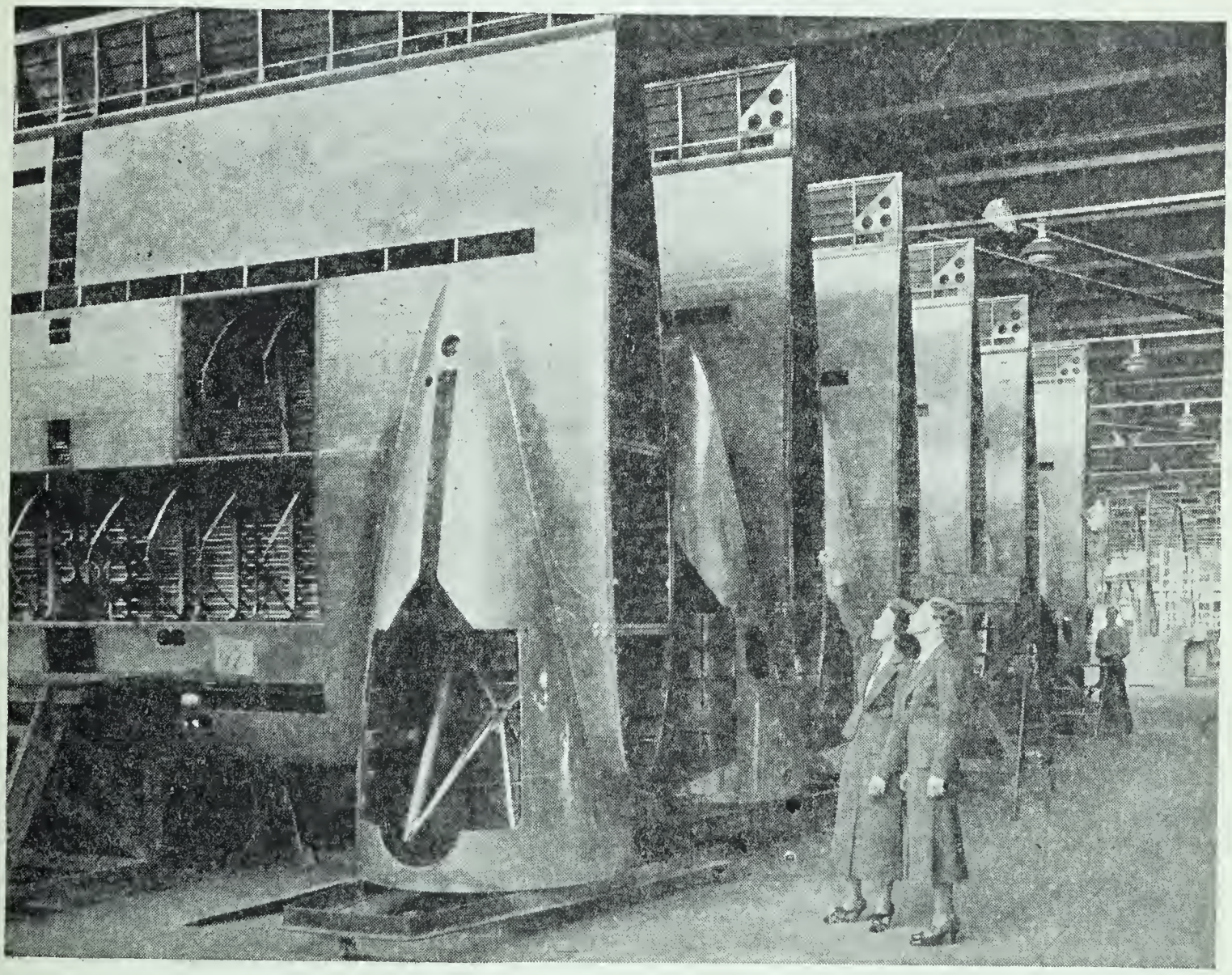


Woodworking Shop, Airplane Factory

scientific planning and wise care for detail. No barnstorming tactics here, no tail spins, and, it was to be hoped, no parachute drops.

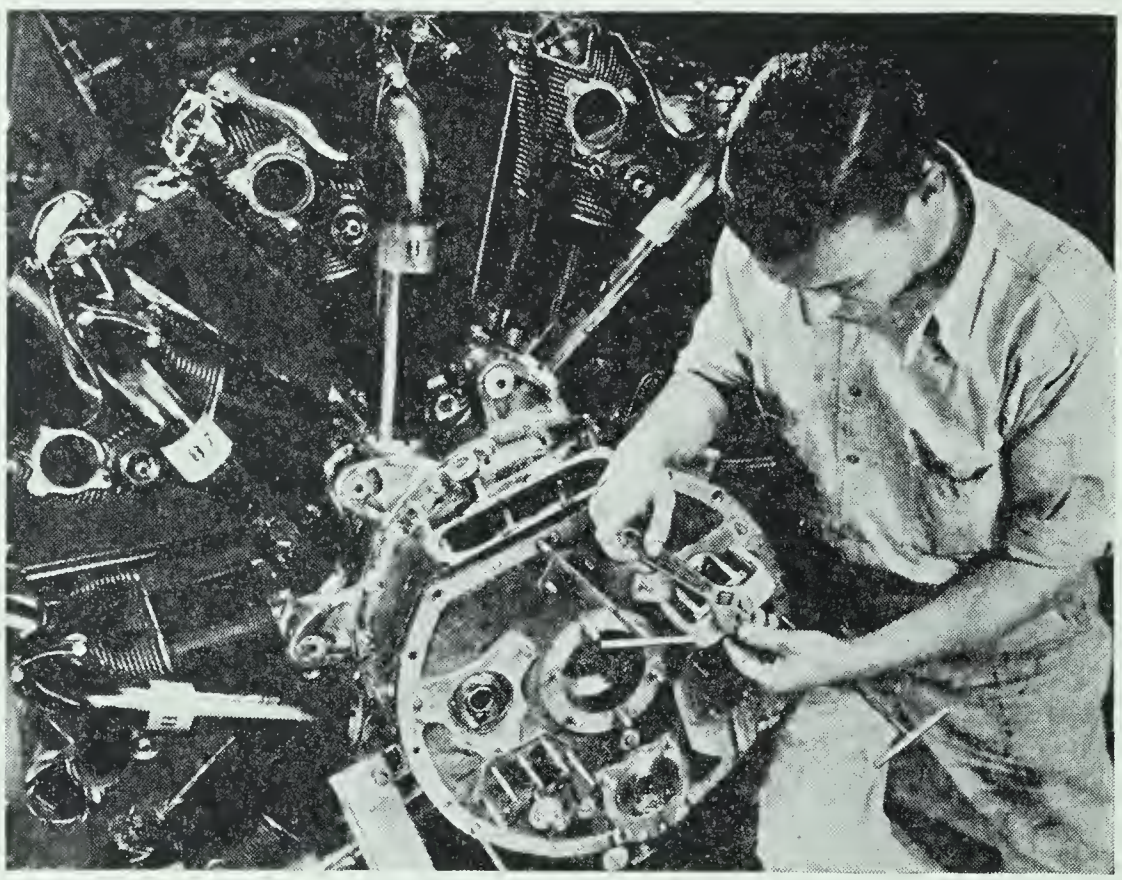
Decisions must be made as to what kind of plane to build. Should it be a biplane or a monoplane? How many motors should it have? What horsepower? What kind of engine? At this time the biplane was most commonly used; but as a monoplane could carry a greater load at higher speed, a monoplane was decided upon. A single-motored plane would have less head resistance, so a single motor was selected—a two-hundred-horsepower, radial, air-cooled engine.

Decisions must also be made as to the equipment to be carried.



Instruments for navigation were being perfected almost daily. Which ones should be used? A full set of the latest was selected, including an earth-induction compass, then a very recent device.

Lindbergh worked out his sailing problems, too. Like the captain of an ocean liner he plotted out his course on big charts, checking his distances by nautical tables on what sailors call the Great Circle, which



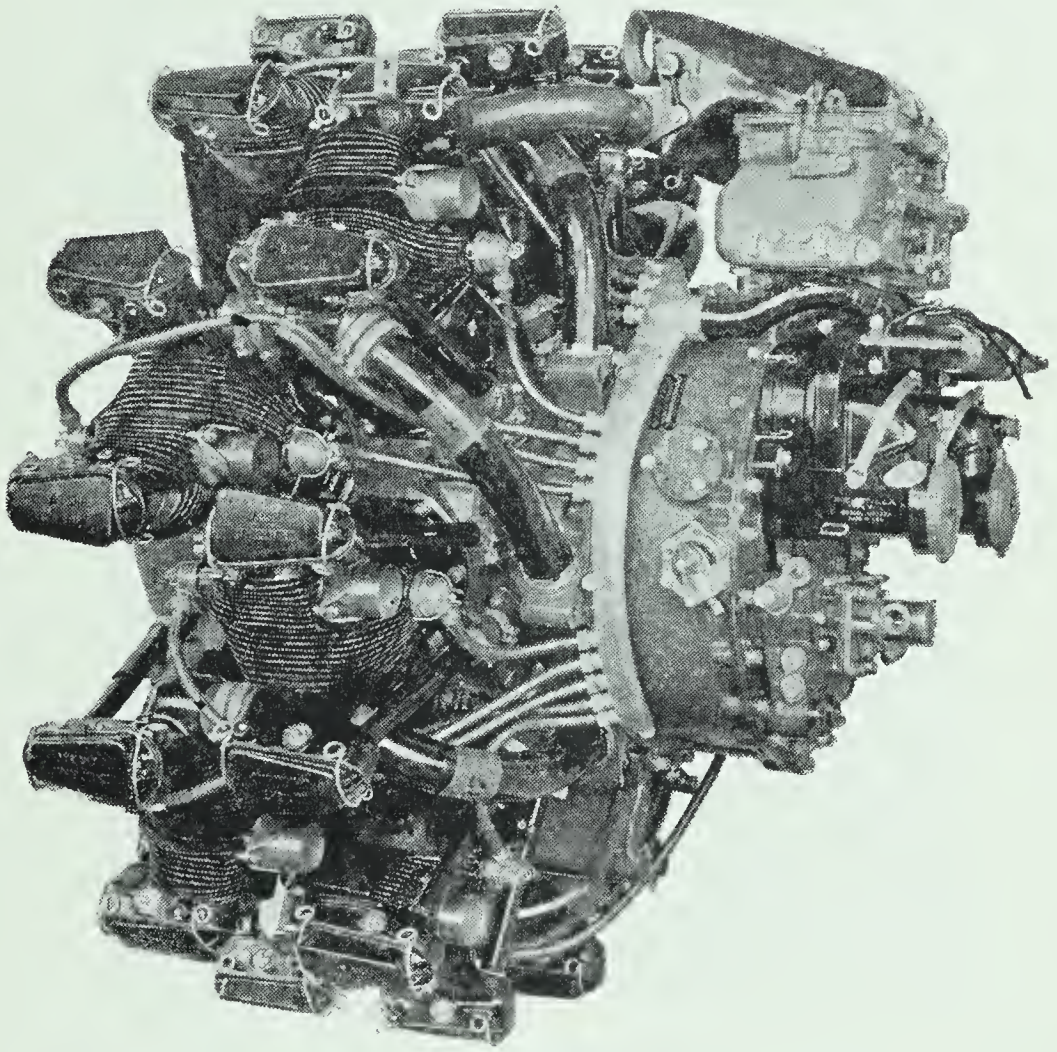
Overhauling the Engine

is merely the shortest distance between two points on the surface of a globe. This was done with great care, changing the course about every hundred miles, or about every hour of the flight.

At last the morning dawned on which the start was to be made. It was dark and cloudy; there were fitful gusts of wind and rain. It certainly looked forbidding; but the aviator had been handed a special weather report the evening before which showed that he would prob-

ably have about as little fog and storm as he could hope for over the North Atlantic.

The runway at the starting field was soft. The plane, the *Spirit of St. Louis*, was loaded heavily with fuel. The machine slowly began to rise. Over a telephone line with barely twenty feet to spare; then over near-by trees, barely skirting their tops, and off into the great ad-



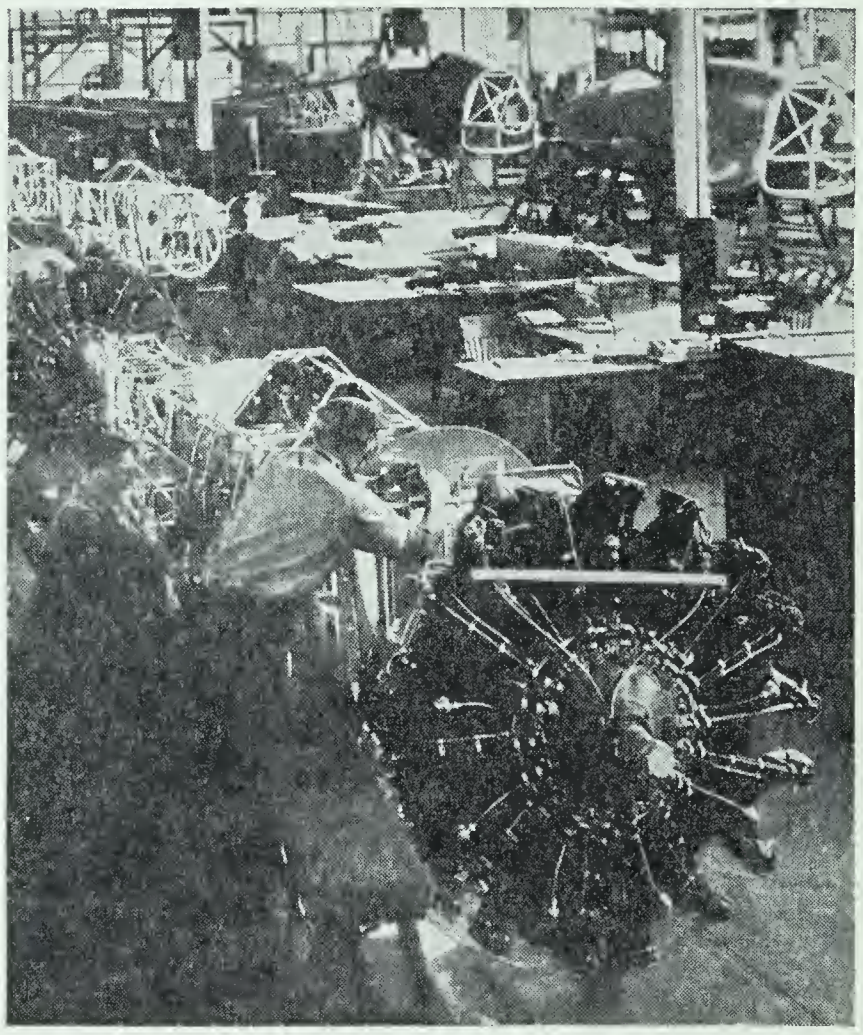
A Radial, Air-cooled Airplane Engine

venture that was to make the name of the pilot resound throughout the world.

We know most of the story after that. Bourget is one of the most important airports in Europe. Lindbergh landed there, guided to the field by the lights of the near-by city. France went wild with its uproarious welcome. Europe heaped honors on Lindbergh's head. America wel-

comed him home again with an enthusiasm it has shown for few men. Why? Who knows just what governs public sentiment? Other men had crossed the sea by air. Other men had planned, and built, and taken part in achievements of equal worth. But somehow the Lone Eagle caught the public imagination as no other aviator had done.

How to turn all this enthusiasm to useful account was a problem

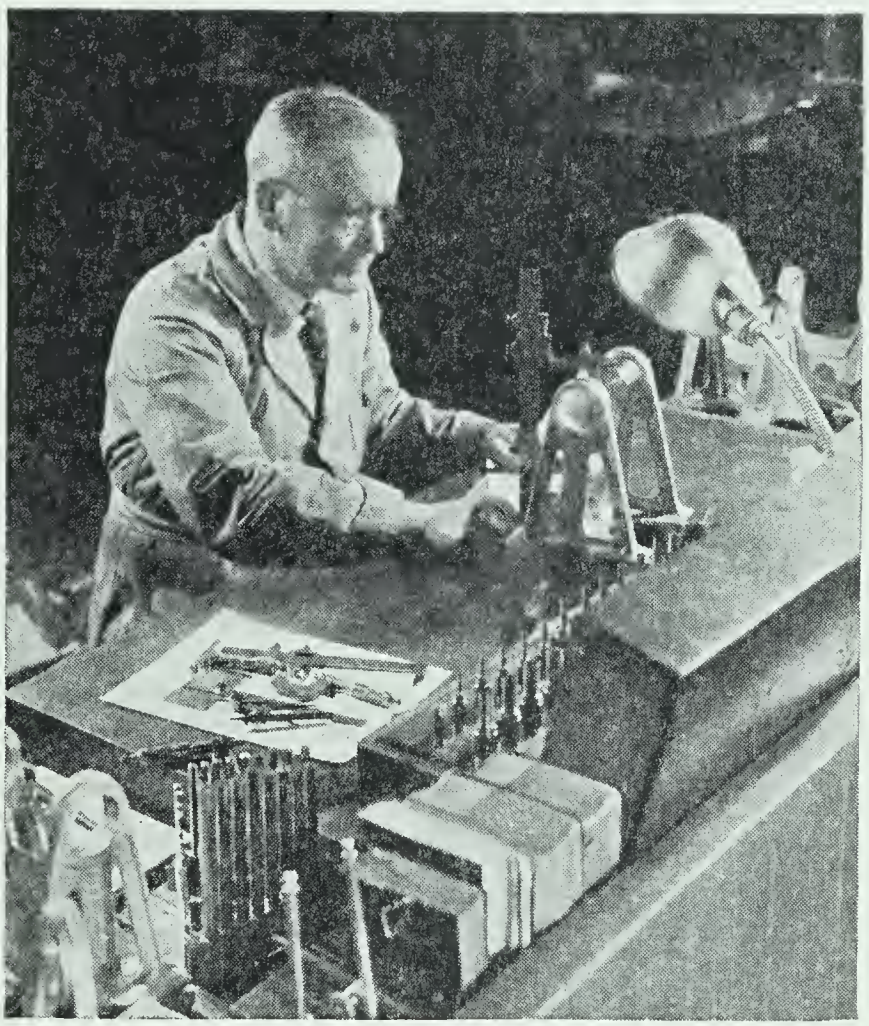


Building Airplane Engines

that now engaged the attention of Lindbergh and his friends. A series of tours was arranged under the auspices of the Guggenheim Foundation. It was the purpose of these tours to have Lindbergh visit the principal cities of the United States while the enthusiasm occasioned by his transatlantic flight was at its height, flying from town to town, and making short addresses at each in an attempt to stir up interest in the subject of airports, landing fields, and commercial air lines.

The influence of this campaign on aviation was marked. New planes were built, new commercial lines opened, new airports equipped. New mail routes, too, were established, improvements were made in air equipment, and people began to talk about traveling by air as if they had always been accustomed to it as a means of getting around.

Attention was drawn, too, to air travel between America and other



One Hundred Per Cent Inspection

lands. Lindbergh made a trip to Mexico with a message of good will, and from Mexico went on to Central and South America. Soon air lines from the United States to Rio de Janeiro, Buenos Aires, and other cities in Brazil, Chile, Argentina, and the islands of the West Indies were opened for business, marking a wholly new era in many of these countries that until that time had been out of touch with the rest of the world.

9

The Air Mail

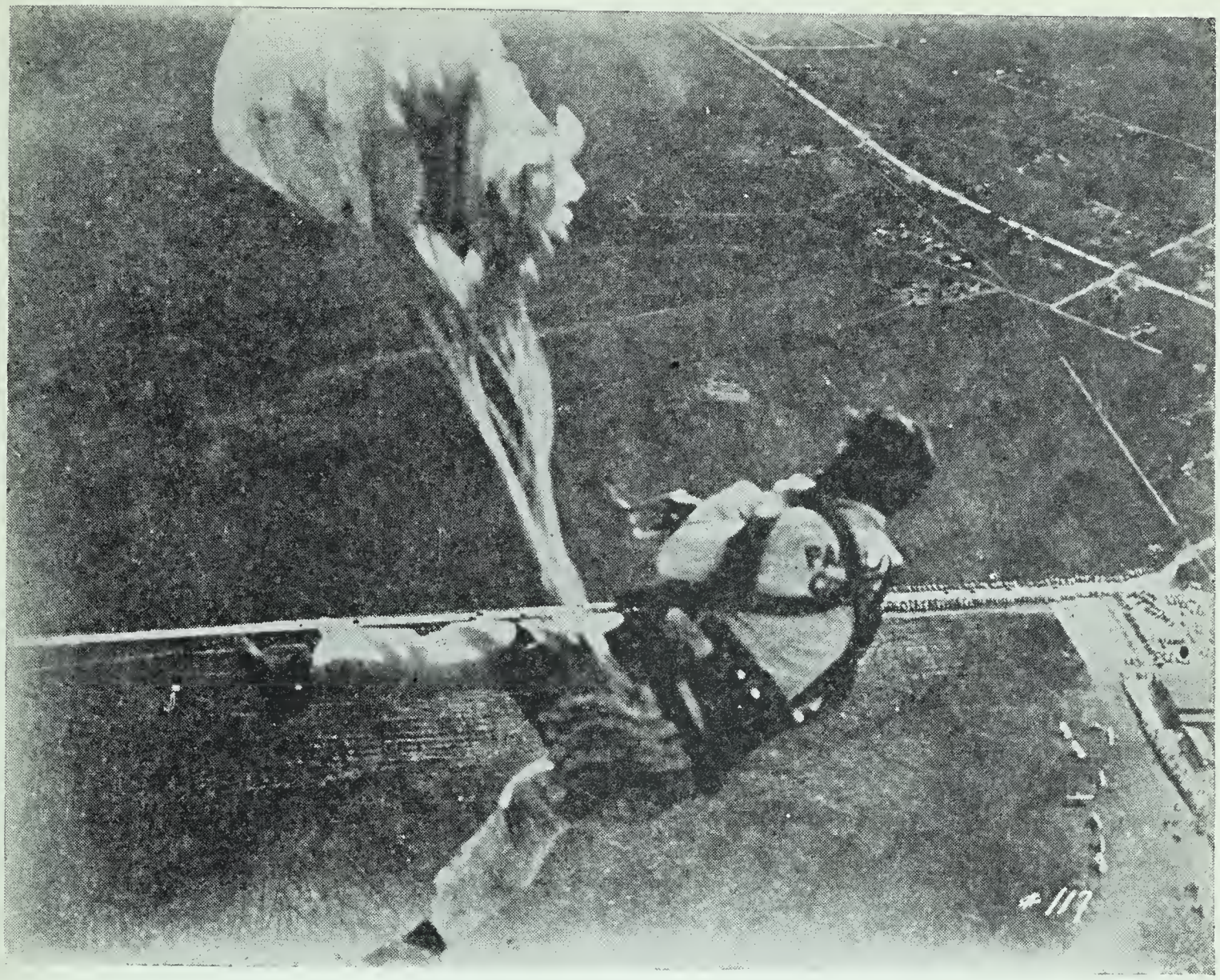
NOT long since, the dispatcher at the Newark airport was talking with the pilot of a mail plane.

"I'm out over the Alleghenies," said the pilot over his radio phone. "Ice is forming rapidly on the wings. The plane is falling steadily because of the ice's weight. Can't stay up much longer. Here I go! Good-by!" And over the side he went.

A few minutes later another pilot called in.

"Ice on my wings. Falling fast. I'm going overboard. Good-by!" and over he went, too.

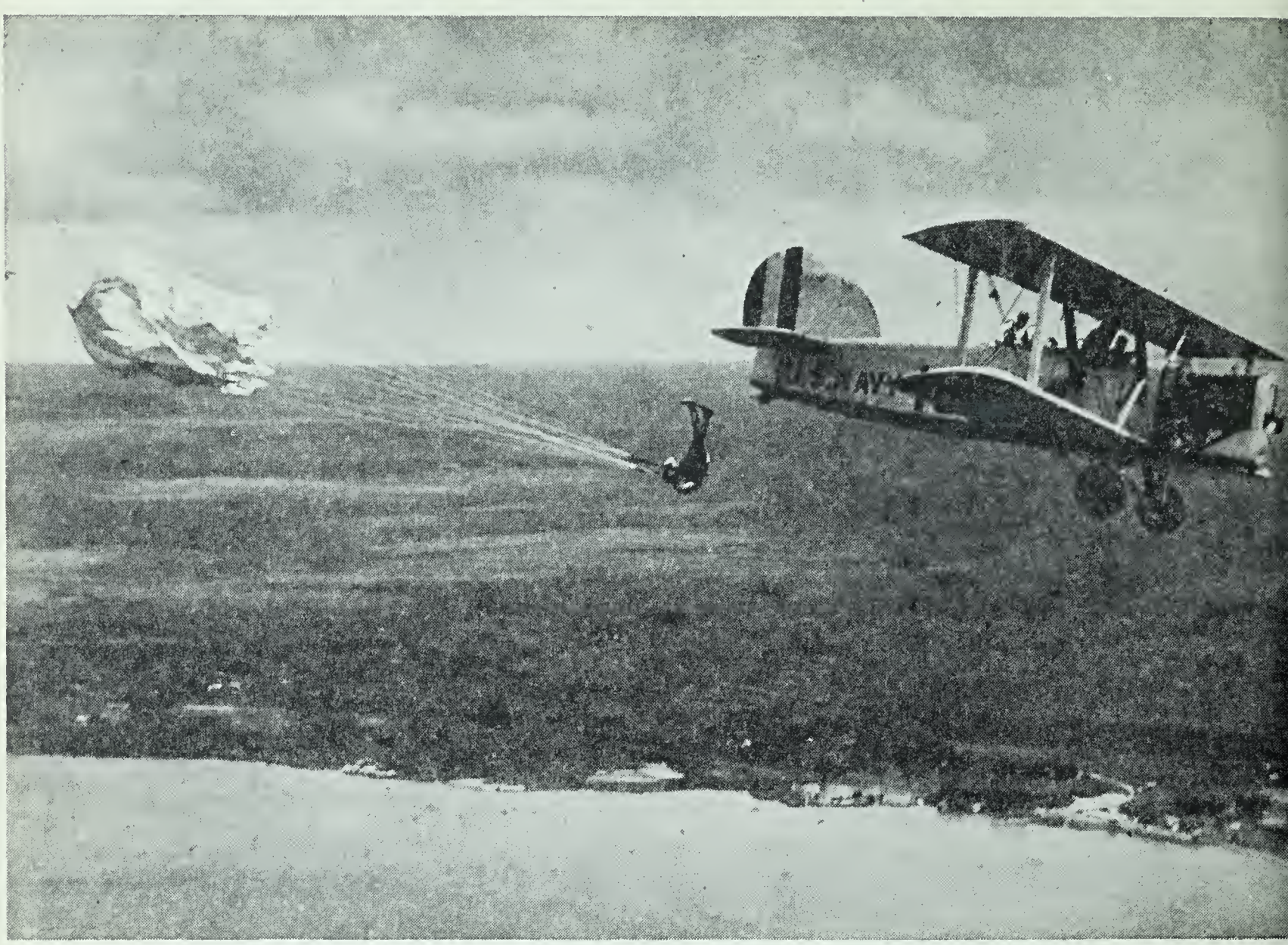
Both men landed safely. Both rescued the mail they had thrown overboard. Both got it to the railroad and had it forwarded by train.



Bailing Out

That is what parachutes are for. The mail pilots think nothing of taking off with one of them. They are to airplanes what air brakes are to a railroad train.

The first air mail in America was organized in 1918. The experiment was made possible by the loan of airplanes and pilots by the War Department. There was a good deal of opposition to the experiment on the part of influential men, who did not think it practicable. But a small sum was set aside for expenses, and a line was established to operate, weather permitting, daily between Philadelphia and Washington. Later it was extended to New York.



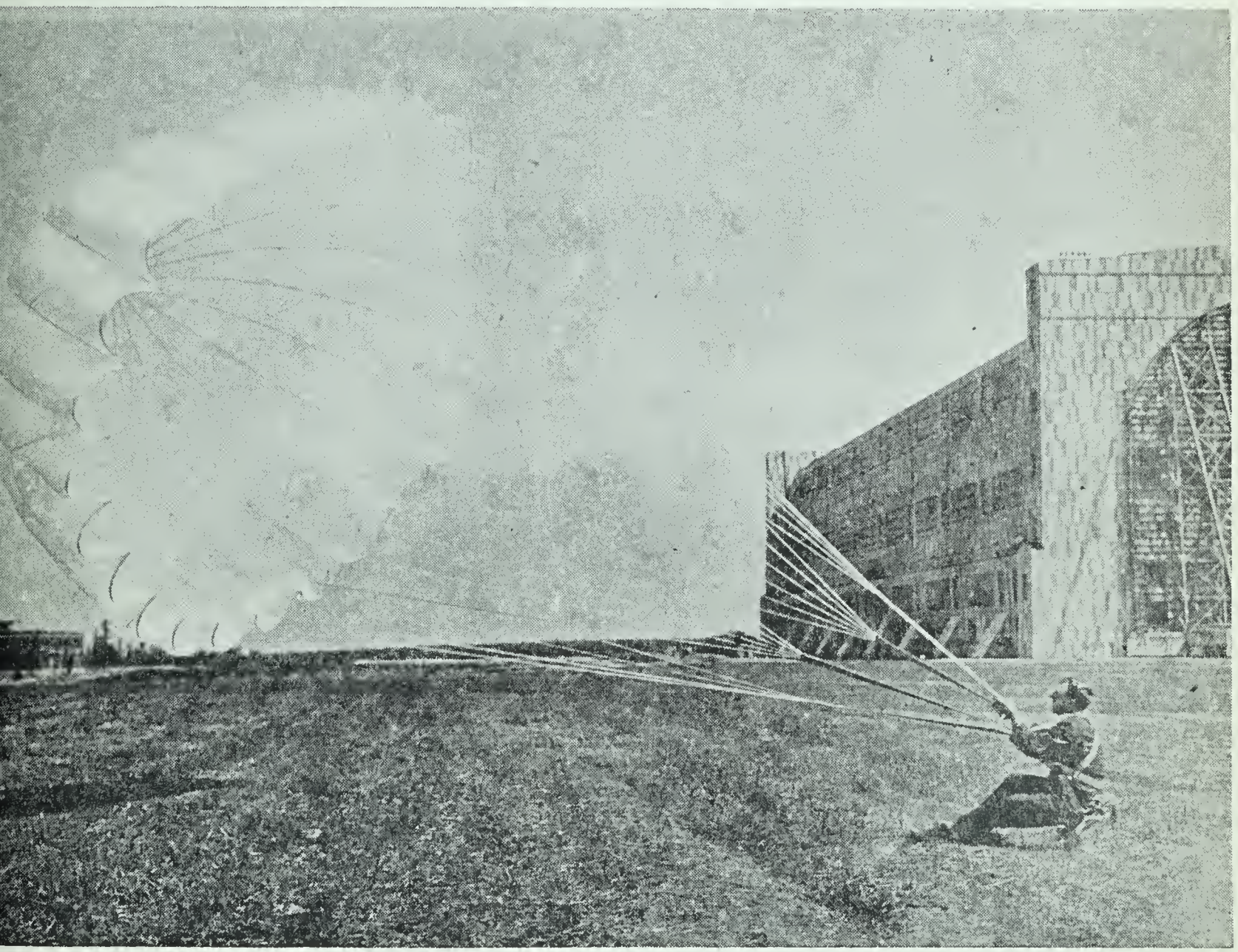
Before the Chute Fills Out

The first plane left Washington with a good deal of ceremony. President Wilson mailed the first letter; he and his cabinet went to the field to see the take-off. Sixty-six hundred letters were in the pouch. Off went the plane! Less than thirty miles away the pilot had to make a forced landing, put the mail on a railway train, and go back to Washington. The southbound plane got through with better luck, flying from Philadelphia to Washington in a little over an hour and a half.

These mail planes did a fine bit of pioneering work. The year after the Washington-Philadelphia line was opened, a line was set up between Cleveland and Chicago. This greatly reduced the mail schedules

between the East and the West, just as the original line had cut down the schedules between New England and the Southern States. A few months after the line between Cleveland and Chicago had been opened, the link connecting it with New York was put into operation. And before long a line from Chicago to Cheyenne was added to the transcontinental system.

One of the remarkable results of this activity in establishing lines of air mail was the establishment of lighted airways. These seemed at that time, before the day when radio beacons and other modern devices had



Bringing Her to Earth

been invented, to be most wonderful aids to air navigation. Landing fields, between Chicago and Cheyenne, were provided every two hundred fifty miles, with a system of auxiliary fields at shorter intervals. On each landing field a revolving electric beacon of a half-billion candle power gave a light which could be seen, on a clear night, a dis-

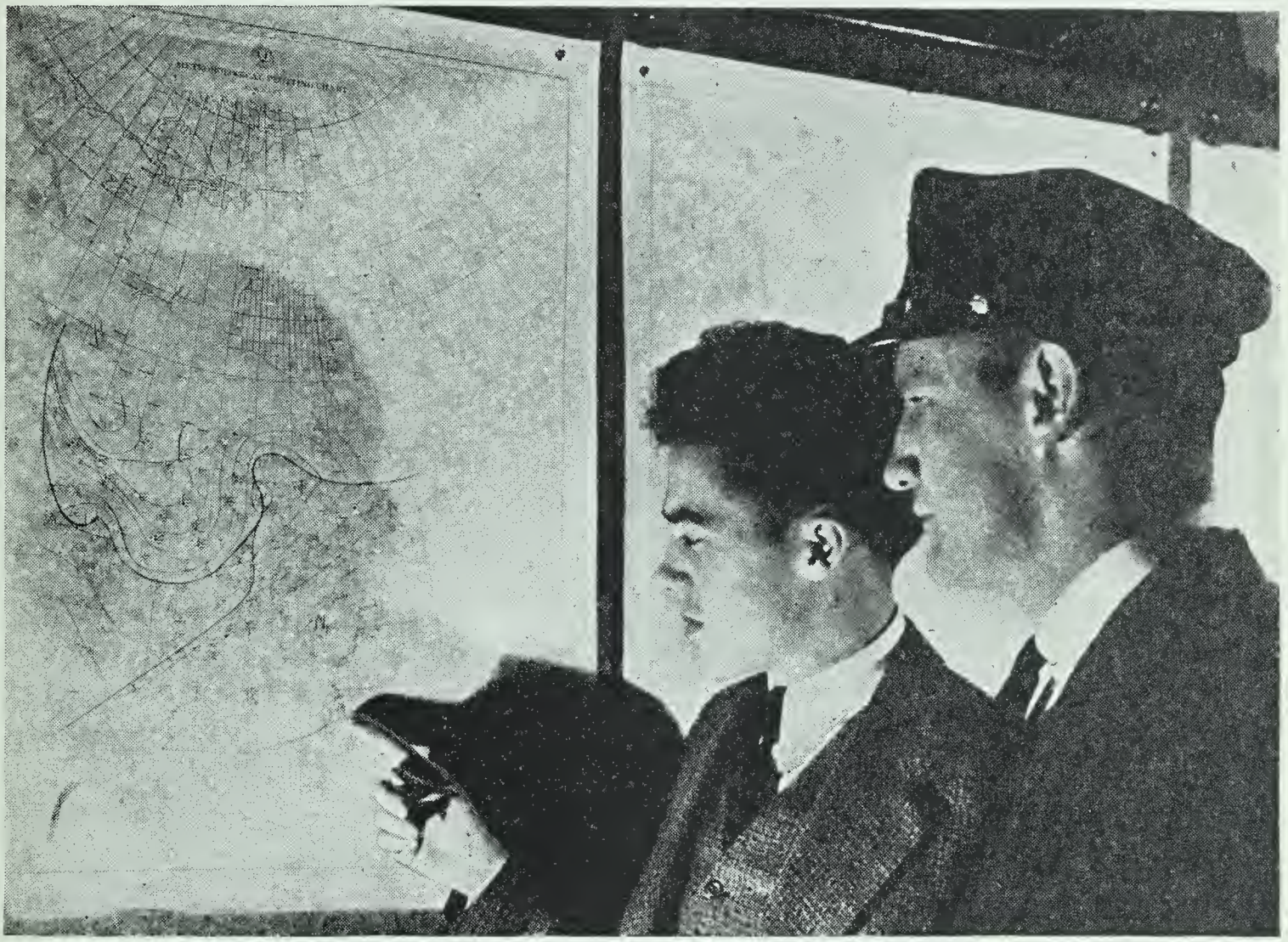
Snowy Morning at the Hangar

tance of a hundred sixty miles. The auxiliary fields had smaller beacons, and all along the route between were "blinkers," or ground lights, placed at intervals of three or four miles.

Now, however, we fly largely by instruments, traveling on a radio beam, and flying at a great height—ten or twelve thousand feet—in what is known as the substratosphere. The planes are constantly in

communication with the landing field, by means of the radio phone through which the pilot talks with the dispatcher, receiving instructions, weather reports, and other necessary communications.

Air-mail flying isn't like racing a plane, going over the route but once, and in weather carefully chosen for the plane to do its best. It is



Before the Start—Looking over the Weather Map

more like a railway train, traveling on regular schedules and defiant of weather and winds. Air mail has grown greatly in volume since that first pouch of letters in 1918. Today we handle over fifteen million pounds of mail by air per year. In the year 1936 air lines in the United States flew 55,380,353 miles.

Beyond our own boundaries, regular mail schedules are maintained

to points in Alaska and northern Canada, to the West Indies, and to points in Mexico, and Central and South America. Planes cross the Pacific Ocean, too, with a weekly mail to Hawaii and the Philippines. Service between New York City and Bermuda has now been inaugurated, the distance between the two points being covered in only five hours. Transatlantic air mail is being planned, to connect Europe and America with a service of much less than twenty-four hours; trial flights for this are now being made before regular service is installed.

While America has been actively leading in air-mail advancement,

New York from the Air

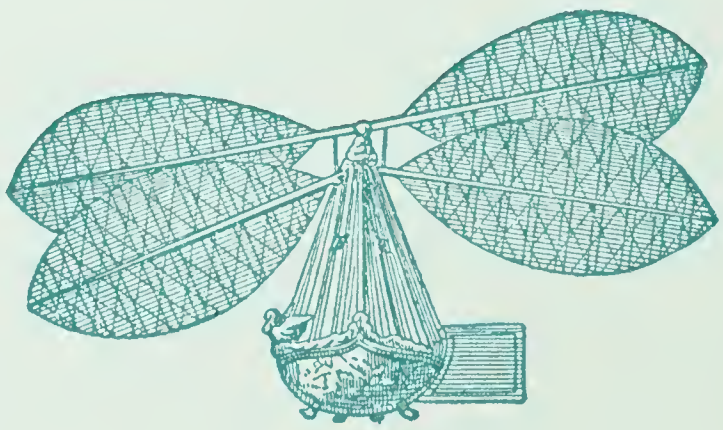
Europe has not been idle. England established air-mail service between London and Paris in 1919, and her air-mail activities have grown until the service extends well-nigh around the whole world. It goes to the English Dominions, with lines to Cairo and Baghdad, to Malta, Egypt, and Jerusalem, and to Karachi in India. In Australia, where the fact that most of the cities are situated on the coast makes intercommunication difficult and slow, air mail has risen to a place of great importance. New Zealand, too, is greatly interested.

The China Clipper Passing Through the Golden Gate, San Francisco, on Her Regular Scheduled Trip Across the Pacific

The French have also been active in air-mail development. They maintain regular service between Paris and such French cities as Lyons, Marseilles, Bordeaux, and Boulogne, and beyond their own borders to Berlin, Warsaw, and Istanbul. Like the English, the French take great pride in their colonies, and their line between Paris and Morocco was one of the first long-distance air routes in the world.

Today we think nothing of sending letters by air mail—fourteen hours from New York to San Francisco, four hours from Chicago to New York, eight hours from New York to Miami, via Miami forty-eight hours to the Panama Canal Zone, and five days to Buenos Aires.

How long will these figures be correct? Builders of airplanes dream of ships that will fly four to five hundred miles an hour. Mail can be sent by air round the world. London and New York, by present plans, will soon be not more than a few hours apart. Who can tell what will be done with air mail in the next ten or twenty years?



10

How Far Have We Come?

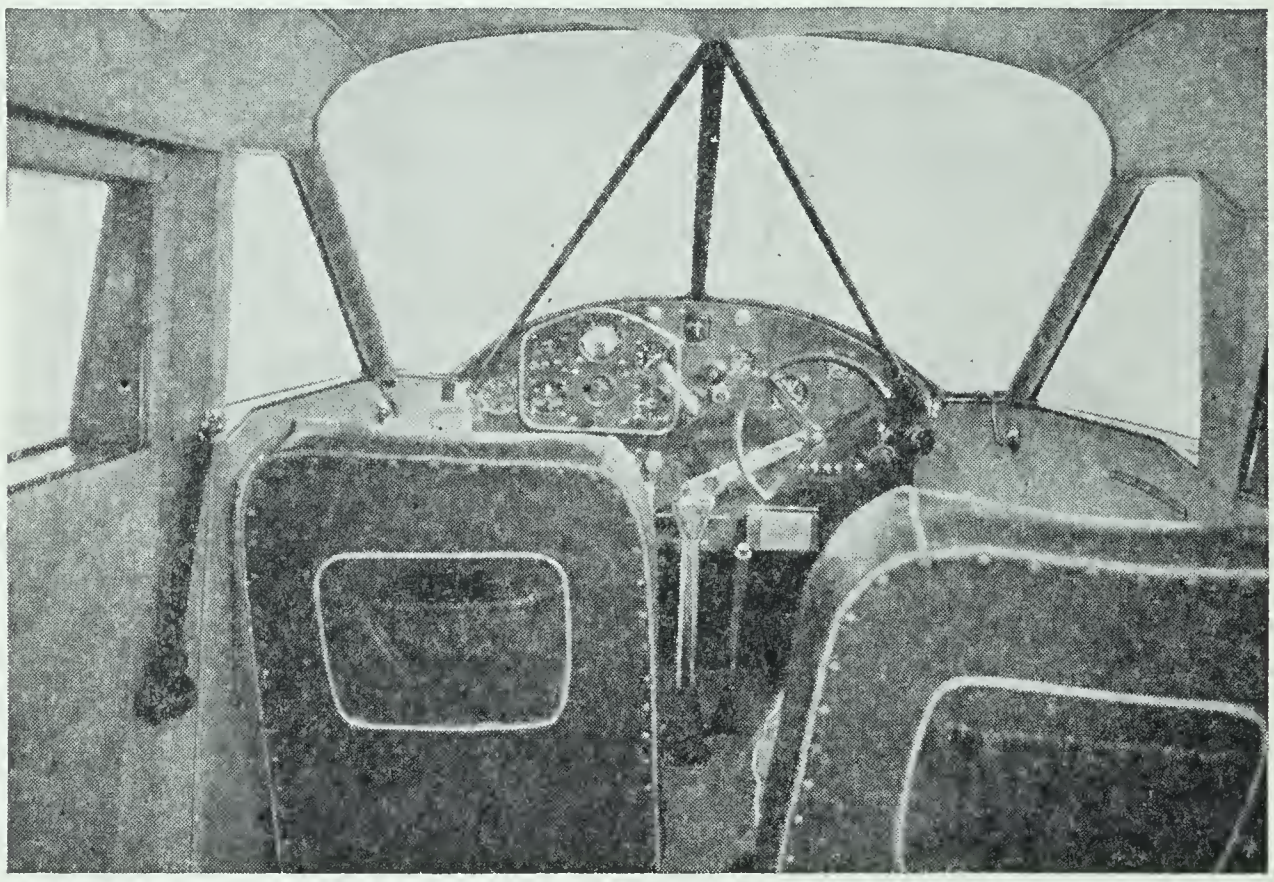
NO NATION can compete with the United States in the development of travel by air. We are doubtless far ahead in both speed and efficiency, and our air lines do more business than all the rest of the world combined.

We fly two hundred thousand miles a day on our regularly scheduled air lines. Over a million passengers a year and seventeen million pounds of mail are carried. Eight million pounds of express matter are shipped by air. We have over five hundred transport aircraft in service, with six hundred pilots, three hundred fifty copilots, two hundred hostesses, and seven thousand five hundred employees and experts on the ground.

Only a few years ago no one thought of a plane that would carry

more than one passenger. Today, great express planes carry as many as forty or fifty. Flying boats that weigh as much as twenty or twenty-five tons fly the seas, loaded heavily with passengers, mail, and cargo. Planes in use on long trips have luxurious and roomy sleeping berths, serve passengers with warm meals, and carry a hostess who is also a trained nurse. Passengers are supplied with nearly every luxury known to travel.

Instruments have multiplied that make for positively accurate navi-

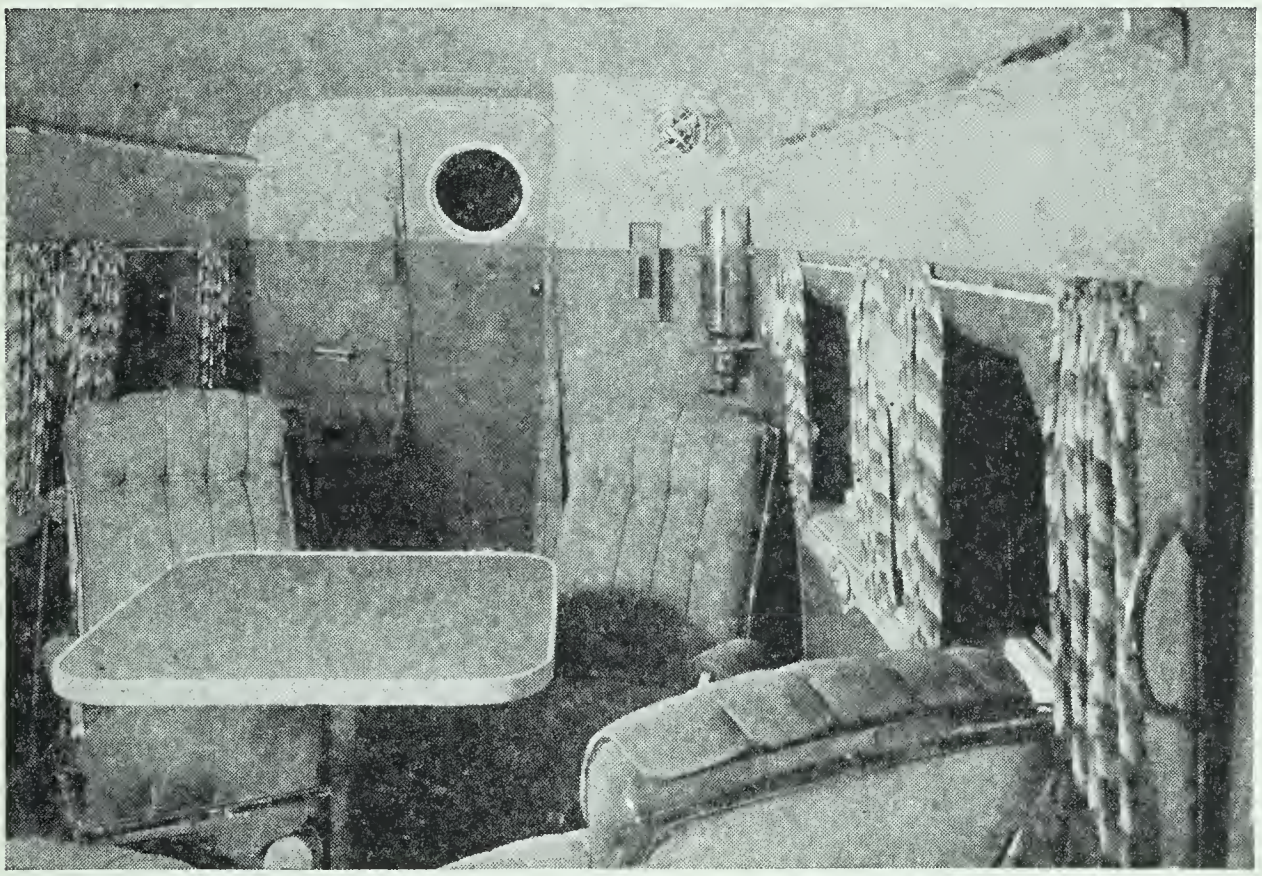


In the Cockpit

gation, and practically all the important lines are now operated on the radio beam. All commercial planes are equipped with radio, usually of the two-way type, by which the pilot may both talk with the dispatcher or with other planes and at the same time receive messages sent by them.

On the Federal Airway System a pilot may use lighted beacons, the Radio Direction Finder, and weather broadcasting, to land in case of

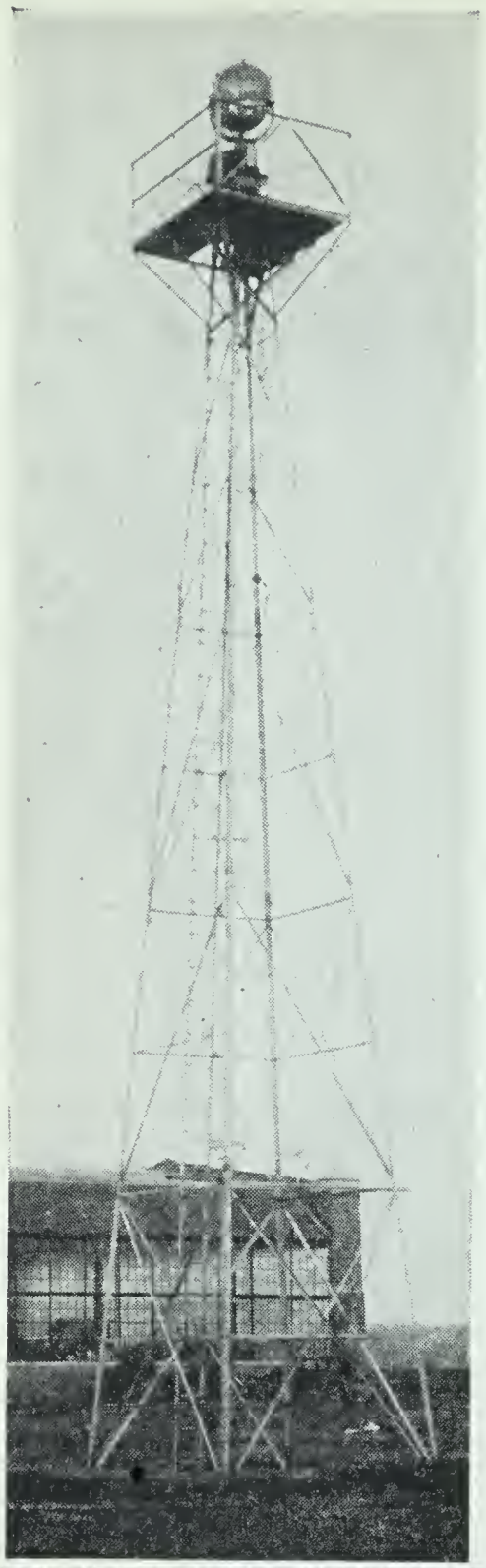
emergency at an intermediate landing field. The Bureau of Air Commerce maintains three hundred of these emergency landing fields, a hundred twenty radio range beacons for directional radio beams, and fifty other radio stations for shorter distances. The Air Traffic Control set up by the Bureau of Air Commerce provides authority to direct all airplane movements over thirty thousand miles of Federal airways. The pilot, the dispatcher and the meteorologist are required to project

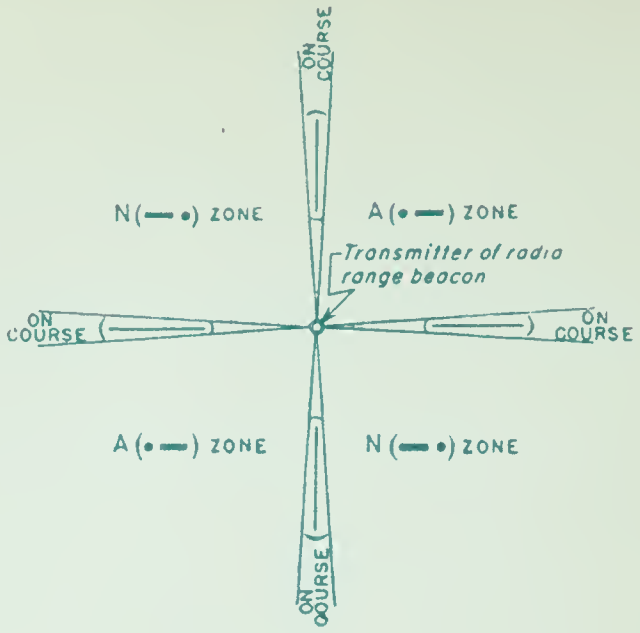


Interior of Private Plane

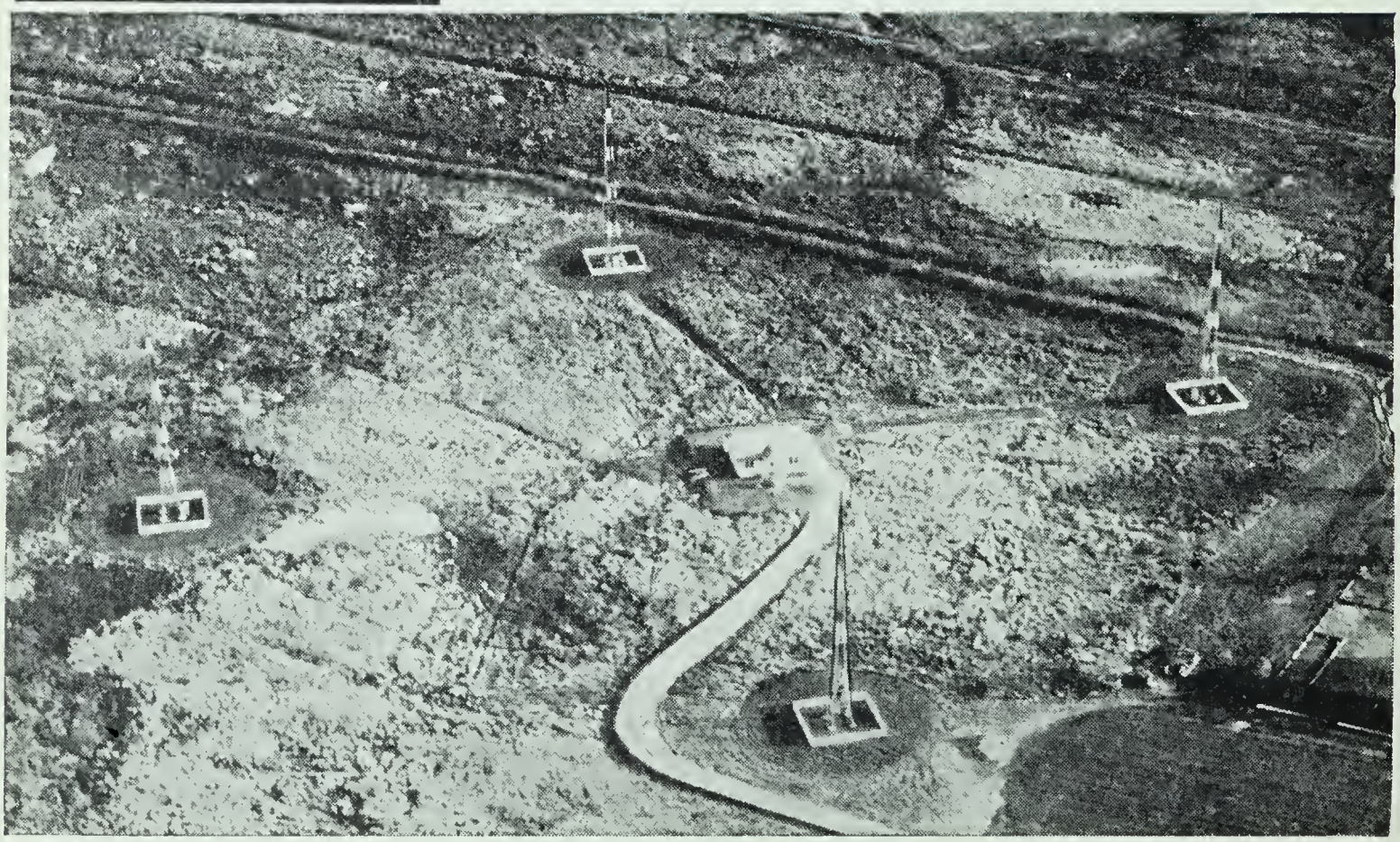
the height, speed, route, and all possible emergencies before setting out with passengers.

Flying by instrument only is now practiced by all pilots of the Army Air Corps, the Navy, and the air-transport lines. With the aid of the directional radio beam this will take the pilot through any kind of weather, even when he cannot see outside his cockpit. This radio beam is made up of *directional electric impulses*. The stations at which the





To the left, a revolving electric beacon, lighting planes to a landing field. At the top, diagram of radio direction beam. Flying on the course the pilot hears a steady hum. Approaching the station, if he is to the right he hears "dash-dot": if to the left he hears "dot-dash." Below is a bird's-eye view of a radio beam station.

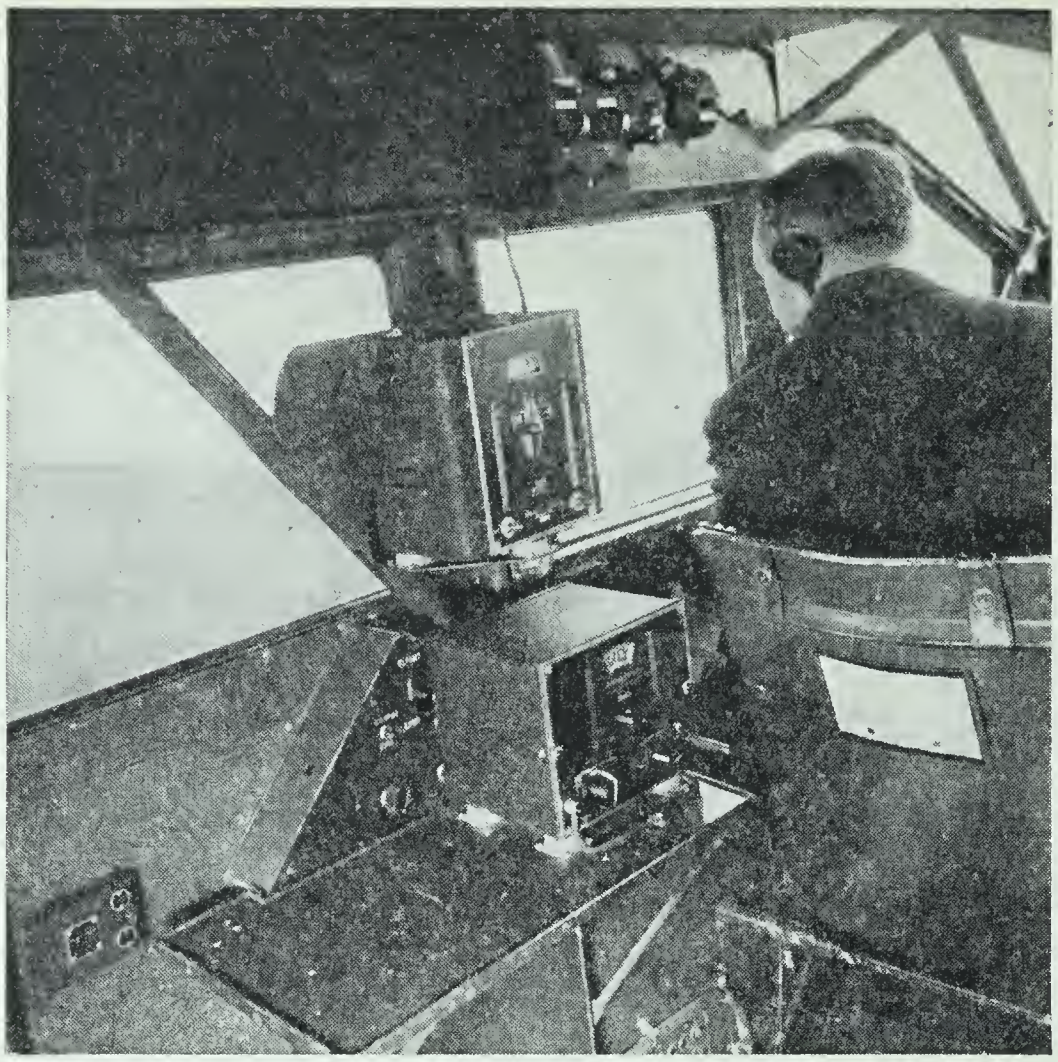


beams originate are set at intervals of about two hundred miles. They send out Morse-code signals along the route continuously. If the pilot is on the right-hand side of the beam he hears a constant ticking—dash, dot, dash, dot. If he is running down the left-hand side of the beam, where he should not be, the call is reversed, and he hears dot, dash; dot, dash; and swerves the plane slightly to the right to get into the proper path. If he hears a mixture of the two, making a constant buzz, he knows that he is riding down the center of the beam.

As he approaches the station from which the beam originates, there is a short break in the signals. This is caused by what is known as the "blind spot," located directly over the station. It gives the pilot, even though the ground below him may be quite invisible, an exact check-up on the position of his plane.

He is also in constant communication with the dispatcher through his radiotelephone. By its use he can report weather conditions, the passage of other planes, or any other desired information; and the dispatcher can give him instructions as to what to do under certain conditions, such as those caused by fog or storm at the landing field, or other emergencies.

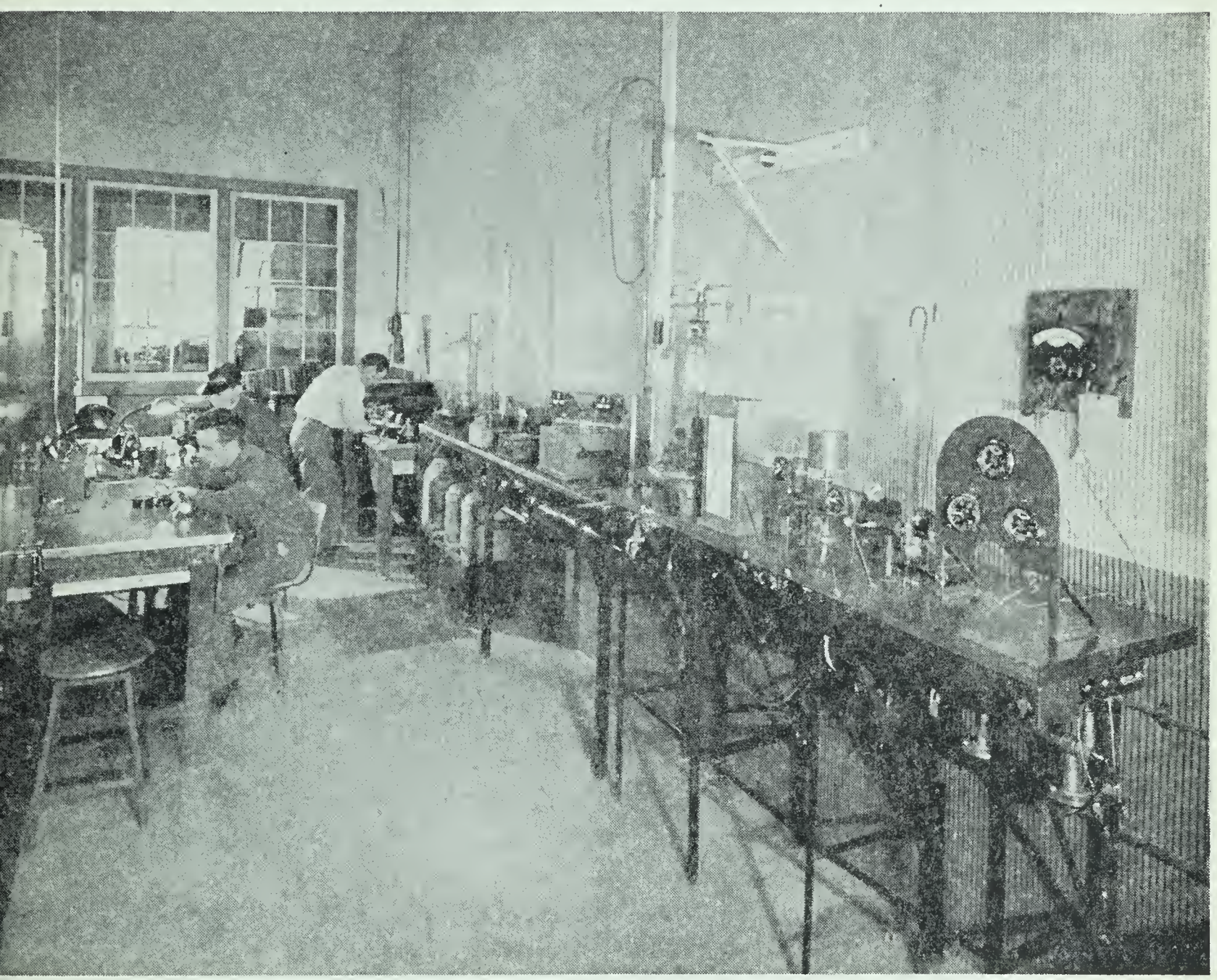
Some amazing things have been accomplished in flight by instrument. In 1935, Commander D. W. Tomlinson took off from Los Angeles with a ten-and-a-half-ton load, climbed the San Bernardino Range, set his propellers for high altitudes, turned on the automatic controls, placed the plane in complete charge of the *gyropilot*, and set out for New York, navigating solely by instrument. He and his companion then sat down in comfort, ate lunch, and toward evening made ready to land in New York—twenty-four hundred miles in eleven hours!



Radio Set for Small Plane

In the Dispatcher's Office

On another experimental flight Commander Tomlinson flew from Kansas City to New York in the substratosphere, about thirty thousand feet up. On this flight he again piloted the plane solely by radio. Returning New York to Kansas City, a hood was placed over the cockpit, so that he could not see outside at all, and using the homing radio

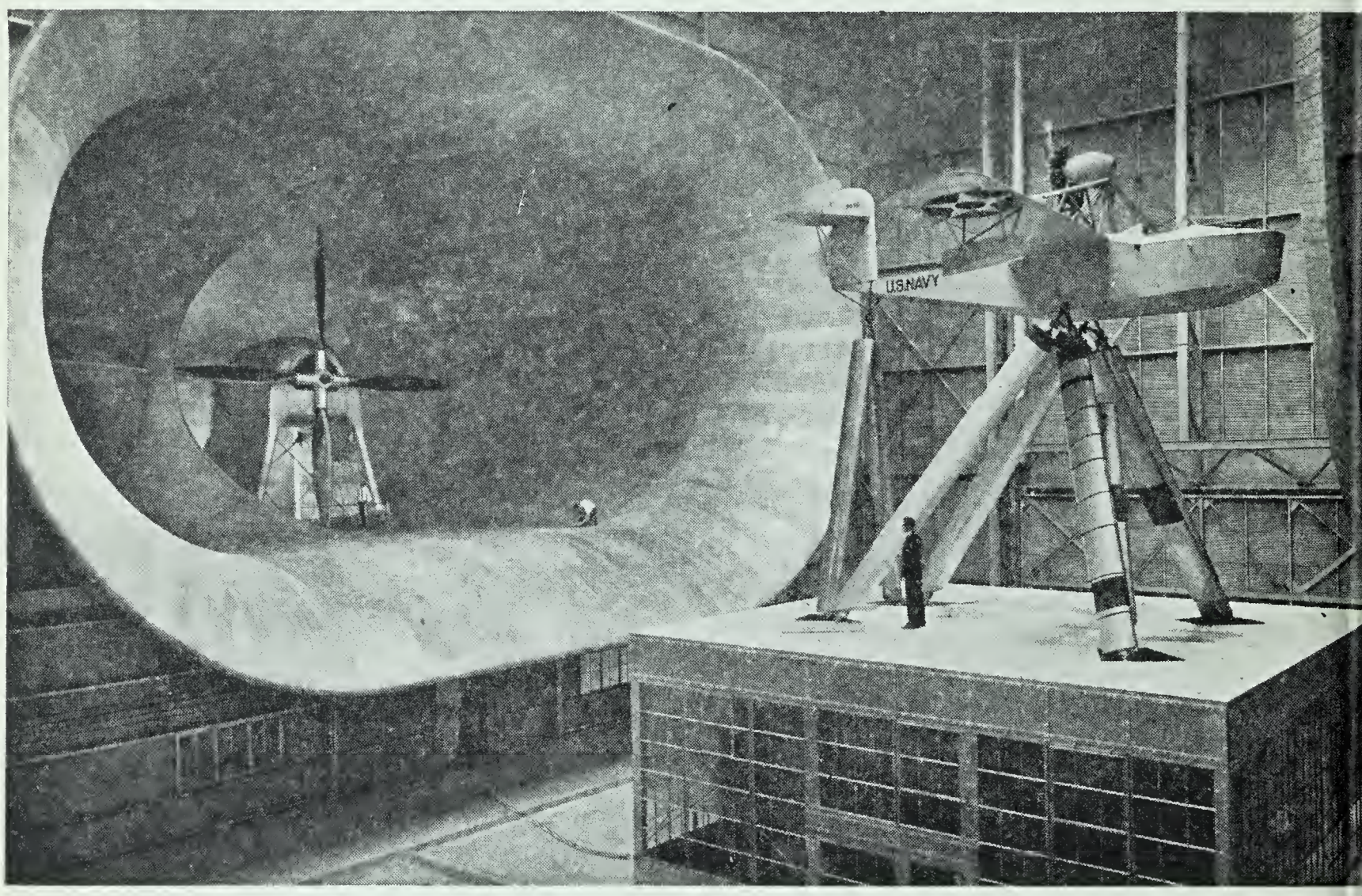


All Instruments Are Carefully Examined and Checked

compass he arrived at Kansas City quite safely and on time. Approaching the landing field, he disconnected the compass, uncovered the cockpit, and made the landing in the usual manner. In the face of unruly

head winds, the plane had made a speed ranging from 165 to 190 miles an hour. And not once was the pilot seriously out of his reckoning.

Today we do a great deal of night travel by air—nearly half of the total. Like the first railways, airplanes did not operate at night when they first came into use. But today over these routes, night and day combined, we are now flying about four thousand passengers, twenty-



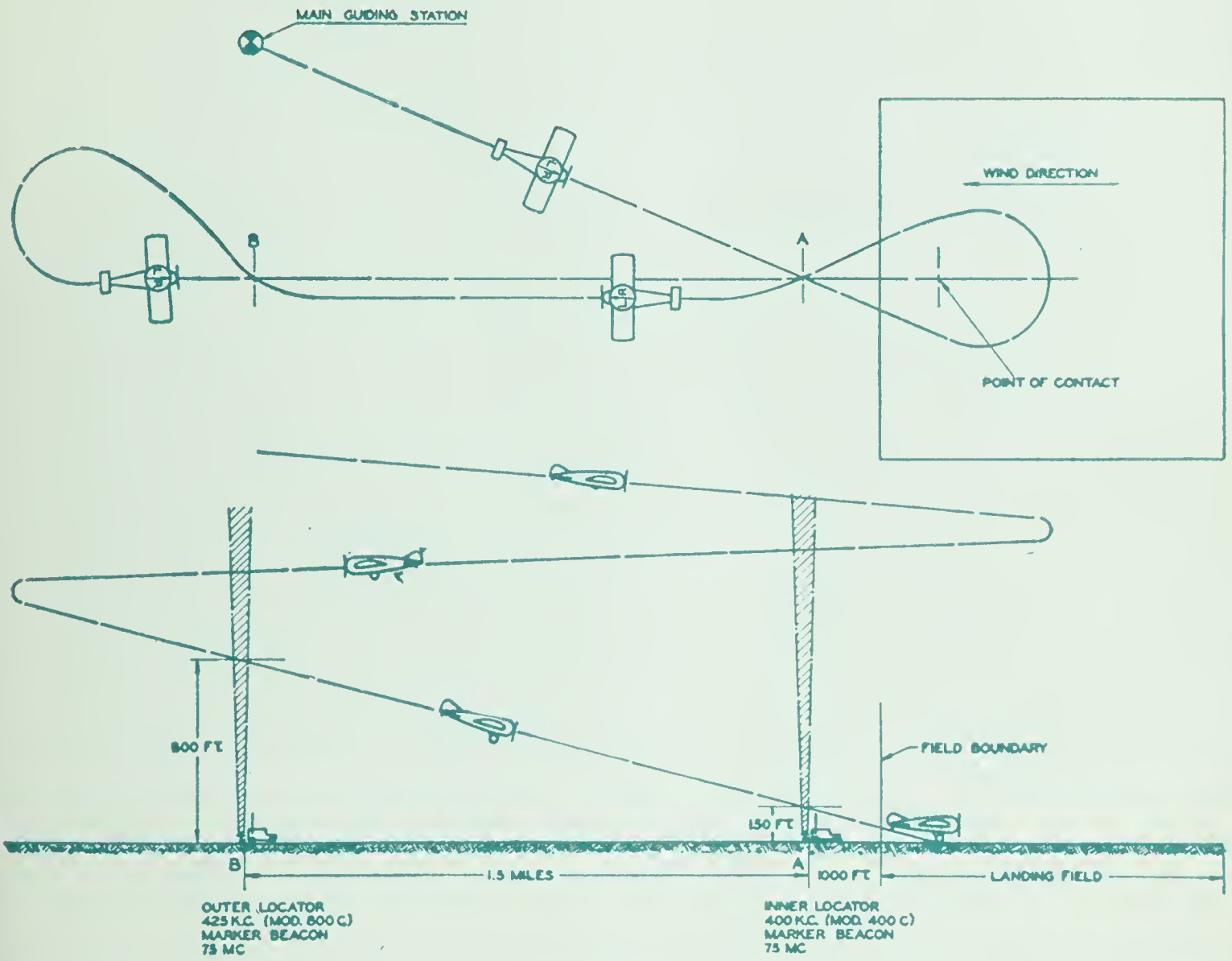
Full-sized Wind Tunnel—Note Size of Men in the Tunnel Mouth

four tons of mail and ten tons of express every twenty-four hours.

Planes make the trip from the Atlantic to the Pacific daily between dusk and dawn. We fly from New York to New Orleans in eight hours, and between New York and Washington in eighty minutes, with fifteen planes in each direction daily. The number of planes in regular

service is increasing steadily; time en route is being steadily reduced.

Journeys that once were measured by days or weeks are now performed in hours. We carry passengers and mail on regular schedules



A Diagrammatic Landing

The upper diagram shows the plane approaching the landing field, passing the main guiding station. The incoming pilot may not be able to see the landing field on account of poor visibility. He hears a steady hum so long as he stays on his course (see page 106). About a mile and one half from the field he flies toward the inner localizer or marker beacon. When he hits the first marker A he hears nothing for about ten seconds according to the altitude of his plane. He pursues his course for a prescribed distance and makes another full turn. Going back he hits the outer marker B while descending on a gentle slant, makes another full turn, and after increasing the downward slant of his machine crosses A again at a height of about 150 feet. He strikes the ground gently at the outskirts of the landing field and taxis across it to a landing stop.

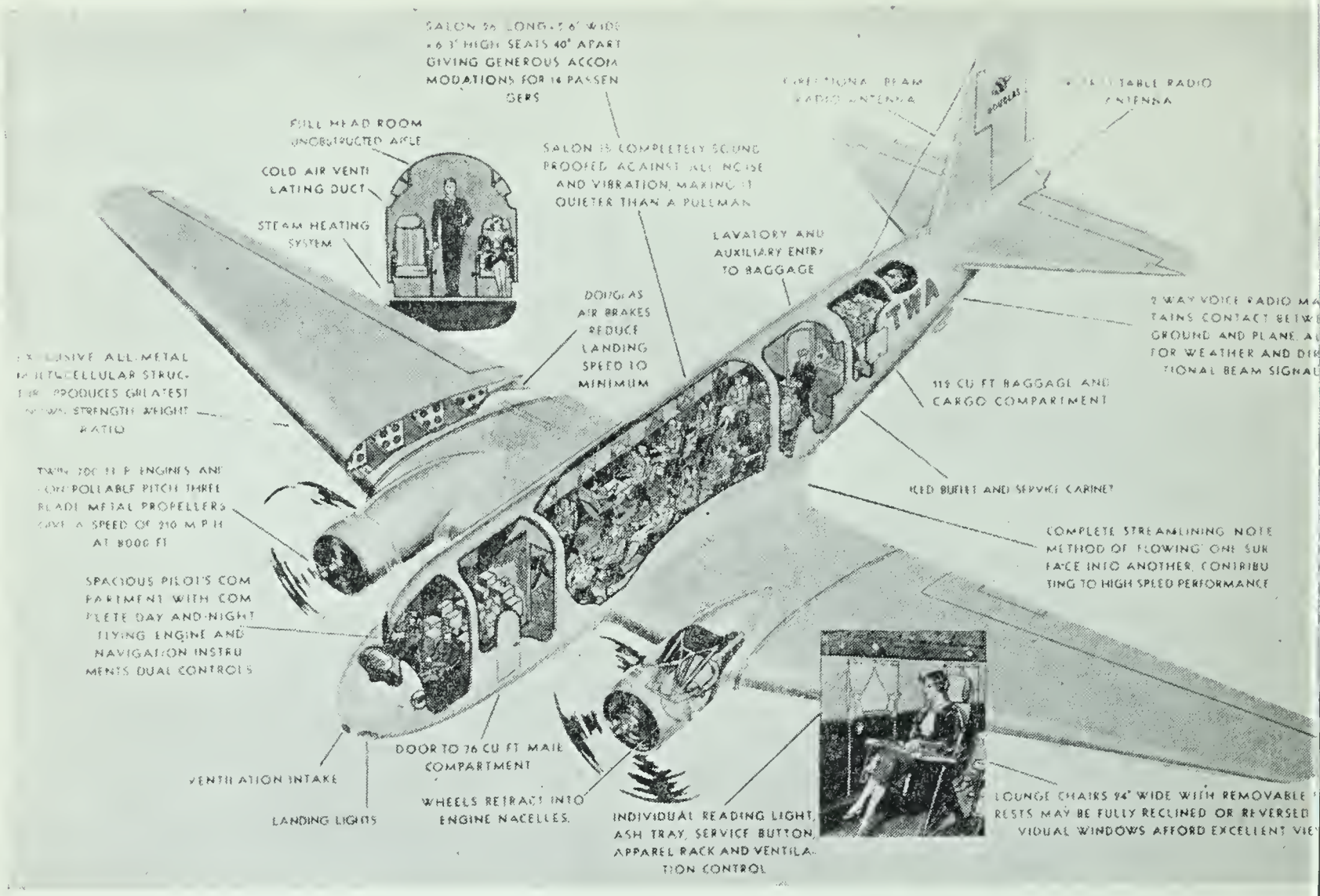
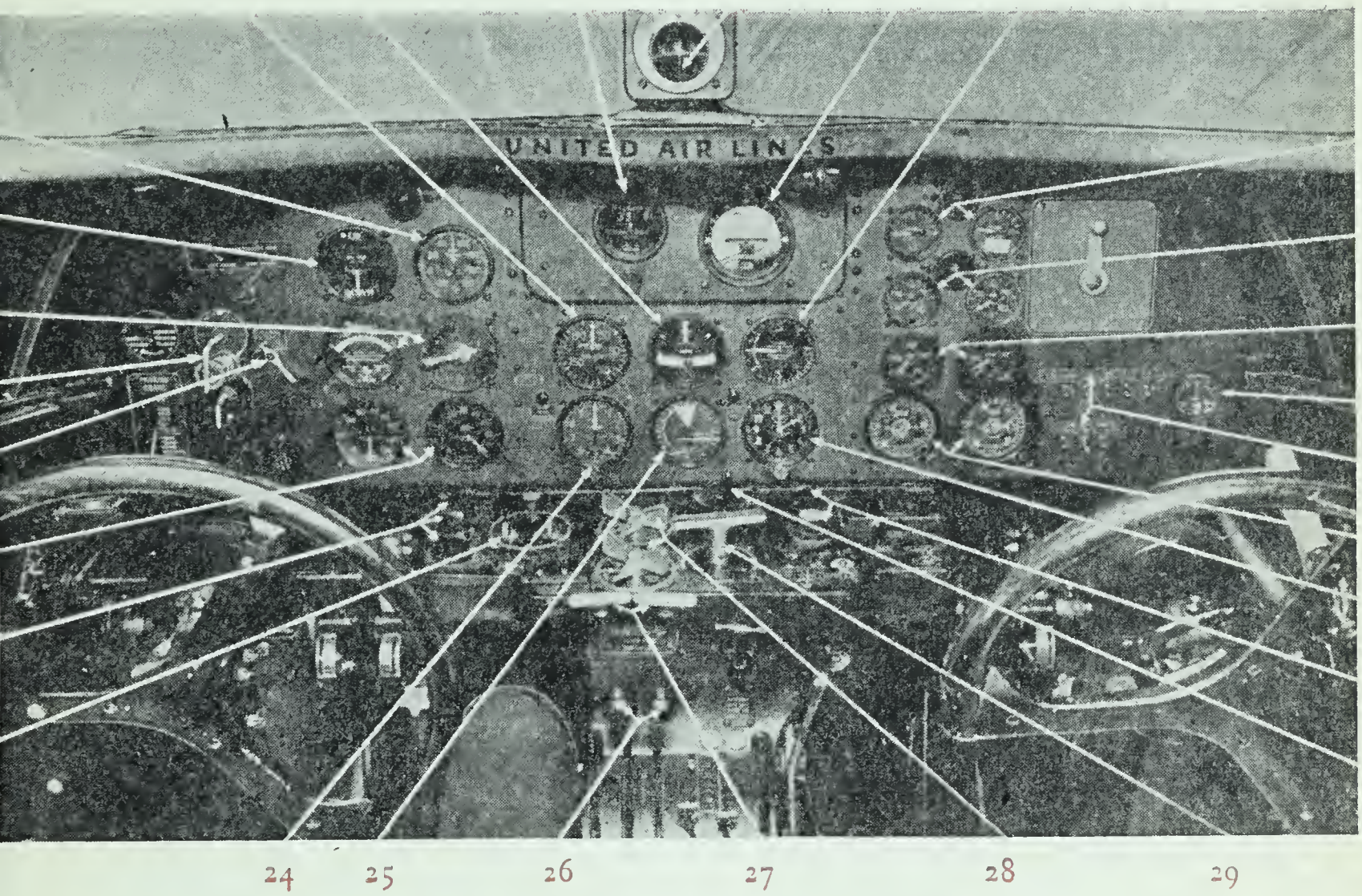

SALON 36' LONG × 7'6" WIDE × 6'3" HIGH SEATS 40" APART GIVING GENEROUS ACCOMMODATIONS FOR 14 PASSENGERS
FULL HEAD ROOM UNOBSTRUCTED AISLE
COLD AIR VENTILATING DUCT
STEAM HEATING SYSTEM
SALON IS COMPLETELY SOUND PROOFED AGAINST ALL NOISE AND VIBRATION, MAKING IT QUIETER THAN A PULLMAN
DIRECTIONAL BEAM RADIO ANTENNA
RETRACTABLE RADIO ANTENNA
LAVATORY AND AUXILIARY ENTRY TO BAGGAGE
DOUGLAS AIR BRAKES REDUCE LANDING SPEED TO MINIMUM
2 WAY VOICE RADIO MAINTAINS CONTACT BETWEEN GROUND AND PLANE, AND FOR WEATHER AND DIRECTIONAL BEAM SIGNALS
EXCLUSIVE ALL-METAL MONOCELLULAR STRUCTURE PRODUCES GREATEST STRENGTH WEIGHT RATIO
119 CU FT BAGGAGE AND CARGO COMPARTMENT
TWIN 700 H P ENGINES AND CONTROLLABLE PITCH THREE BLADE METAL PROPELLERS GIVE A SPEED OF 210 M P H AT 8000 FT
ICED BUFFET AND SERVICE CABINET
COMPLETE STREAMLINING NOTE METHOD OF FLOWING ONE SURFACE INTO ANOTHER, CONTRIBUTING TO HIGH SPEED PERFORMANCE
SPACIOUS PILOT'S COMPARTMENT WITH COMPLETE DAY AND NIGHT FLYING ENGINE AND NAVIGATION INSTRUMENTS DUAL CONTROLS
DOOR TO 76 CU FT MAIL COMPARTMENT
VENTILATION INTAKE
LANDING LIGHTS
WHEELS RETRACT INTO ENGINE NACELLES
INDIVIDUAL READING LIGHT, ASH TRAY, SERVICE BUTTON, APPAREL RACK AND VENTILATION CONTROL
LOUNGE CHAIRS 24" WIDE WITH REMOVABLE RESTS MAY BE FULLY RECLINED OR REVERSED
VIDUAL WINDOWS AFFORD EXCELLENT VIE

Diagram of Modern Plane

that run as high as three miles a minute. We build special planes that can fly from three to four hundred miles an hour. We maintain twenty-eight thousand miles of regular flying routes in the United States, and twelve thousand miles in foreign countries. Flying boats make regular schedules over the latter—boats that weigh twenty to twenty-five tons, carry forty or more passengers, and five thousand pounds of freight.

Only a few years ago there was as yet no control over who should be permitted to fly, or when, or what kind of machine he would be permitted to use. Now the government, under the Department of Air Commerce Act, passed early in 1926, regulates all that.

The Department of Air Commerce maintains a system of inspectors



The Controls

1. Air-Speed Indicator; 2. Turn and Bank Indicator; 3. Directional Gyro; 4. Compass; 5. Artificial Horizon; 6. Rate of Climb Indicator; 7. Fuel Pressure Gauges; 8. Oil Pressure Gauges; 9. Oil Temperature Gauges; 10. Ammeter; 11. Switch Bank; 12. Tachometers; 13. Clock; 14. Radio Volume Controls; 15. Radio Tuning Dial; 16. Air Temperature; 17. Retractable Wheel Indicator; 18. Thermocouple and Selector; 19. Primer; 20. Selector; 21. Gasoline Gauges; 22. Rheostats for Lights; 23. Engine Switches; 24. Sensitive Altimeter; 25. Pressure Gauge; 26. Throttles; 27. Propeller Pitch Controls; 28. Gasoline Tank Selectors; 29. Elevator Flap Adjusters.

who examine the pilot as to his fitness, watch his work, and give him a license if and when he is entitled to it. These inspectors examine the school in which he has studied and the airport from which he takes off. They examine the ship he goes out in, and the factory in which the ship is built. They say how he shall fly, how high over each town he

Alaskan Air Travel

must remain, and how and where he is to land. They supply him with weather reports, and control the radio with which his plane is equipped.

At an airport such as that at Newark, N. J., or at Los Angeles, Calif., there are from a hundred fifty to two hundred arrivals and departures each day. This requires a thoroughly reliable and complete system of control over all ships approaching or leaving the field. This control

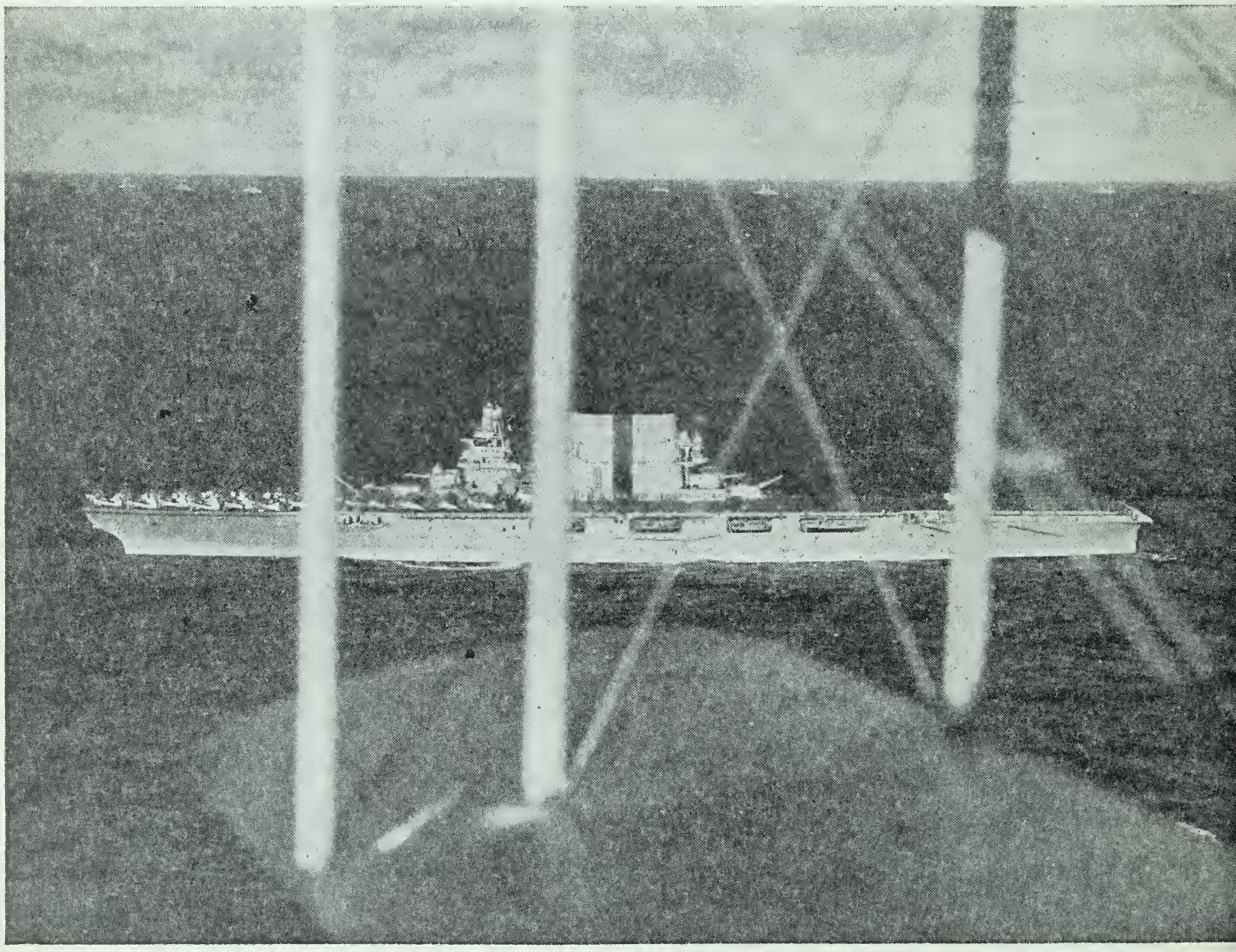
is exercised from the dispatcher's office, with the aid of some of the most remarkable mechanical devices known to man.

There are sixteen thousand licensed pilots in the United States, with twenty-two thousand student pilots, and over seven thousand planes. The pilots are a capable and experienced lot of men. More than twenty-

An Autogiro in Flight

five of these pilots hold a record of having flown a million miles or more. But the careful supervision of the government is supplemented and continued by the management of the lines for which they work. Before the pilot can sign out and get his clearance card, without which his plane cannot start, he spends an hour or more at the airport in

preparation. Weather bulletins from all parts of the country are posted hourly on the bulletin board in the operations office. He goes over these carefully. He studies them and the weather map in company with the dispatcher and the meteorologist, poring over them carefully as he plans his trip, the route by which it is to be flown, the altitude, and the speed. In fact, if conditions are not good, he or the dispatcher must determine whether to make the flight at all. The last word is the pilot's. If he says *no*, there is no recourse; he will not make the flight, nor will any other pilot be asked or permitted to take his place.

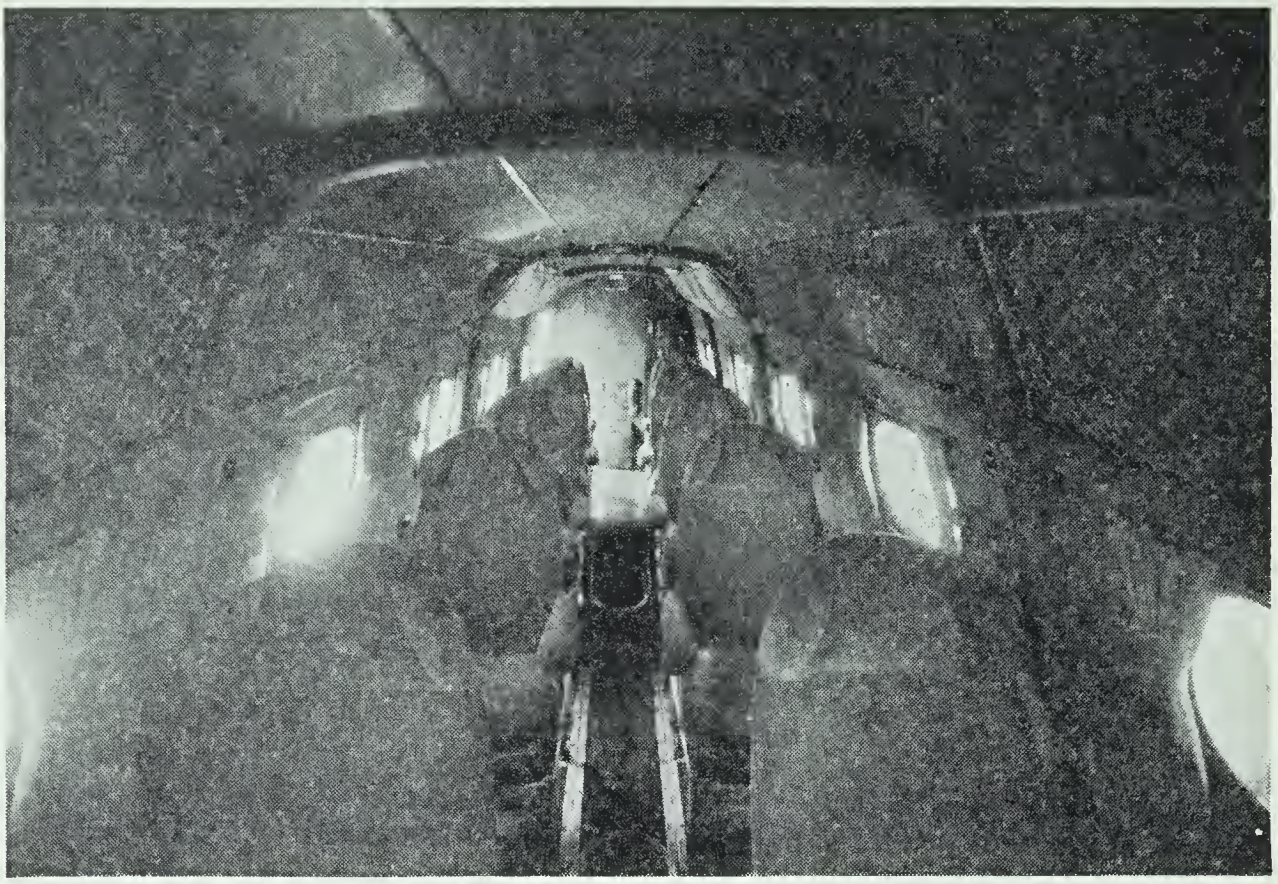


A United States Airplane Carrier

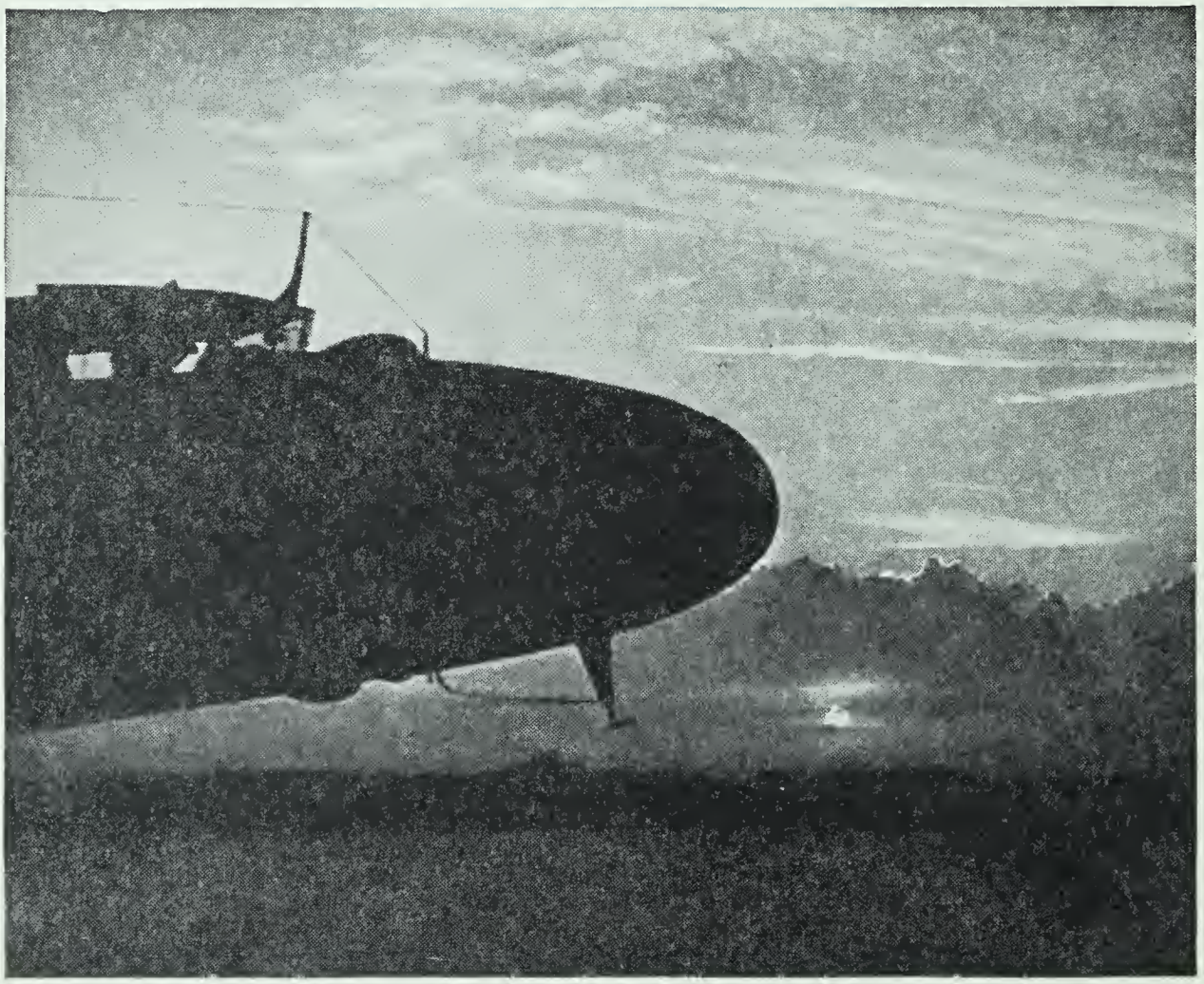
Meanwhile, mechanics have been going over the plane. It is carefully inspected at the end of each trip; and at the end of every four or five hundred hours of flying it goes into the shops to be completely overhauled. Instruments, radio sets, and generators are replaced at frequent intervals. Even after the plane taxis out on the runway, each engine is tested to make sure the jolting over the field has not affected it.

Coming into the airport is an operation that is carefully planned and guarded. There must be four hundred feet of ceiling over the field at the end of the journey, or the dispatcher will not let the plane go out. To an aviator the ceiling is the distance from the earth to a fogbank or cloud that shuts off his vision. "Ceiling zero" means that there is no visibility whatever; fog or mist shuts off all vision, clear down to the ground. Should this ceiling be lowered before the plane arrives, the dispatcher will order the pilot to change his course and land at some other airport. At Newark, and other fields where the traffic is heavy, the various lines using the port use different altitudes as they approach the checking points that lead to the airport.

All this is part of what is known as *ground organization*. Someone has said that ninety per cent of the work of flying is done on the ground. That is because flying is much like running your automobile. You want oil and gas, and repairs, and spare parts; you want highways that are plainly marked so that you will not lose your way. In flying you also have to know all about the weather ahead of you; if you are a passenger on one of the longer runs, you must be sure of a place to eat and sleep. There must be a landing field, too, always within easy reach. For you never can tell when you may have to land in an emergency. When you do, you will need men to help you get the ship into the hangar,



In a Modern Air Transport



Ready for the Night Flight

mechanics to go over the ship, and oil and gas to help you on your way.

With all the rules and provisions for safety it looks as if there is but little for the pilot to do. But he does much. For after all, safety depends, in an emergency, upon the cool judgment and ready alertness of the man in charge. Good pilots develop an instinct for flying. They can't tell you just how. But there it is! When emergencies come, all the fine equipment and all the rules of government experts are of little use unless they are in the hands of a man who is courageous and skillful and whose judgment is without fault.

We haven't reached the point where we can do as Santos-Dumont did and fly our own airplane to our own door. When that time comes, flying will be within everyone's reach.

Planes are being talked of that will make speeds even greater than we now hear of. To do this, they will fly in the stratosphere, above the contrary winds, and where the atmosphere is light. That means ten or twelve miles above the earth.

Commander Tomlinson has recently been making flights of this character, conducting what he calls experiments for *over weather*. For this purpose he proposes that planes be built with a capacity for carrying fifty passengers, with high-powered engines—large planes, measuring a hundred fifty feet from tip to tip of the wings. Such planes would make a speed of three or four hundred miles an hour.

One difficulty with this question of increased speed has been the problem of speed in landing. Quite a great deal has been done toward solving the problem; but much remains before the higher speeds can be practical. As we have said in a former chapter, before a man can learn to fly, he must know how he is going to land!

A Glider

Do I hear someone say *helicopter?*

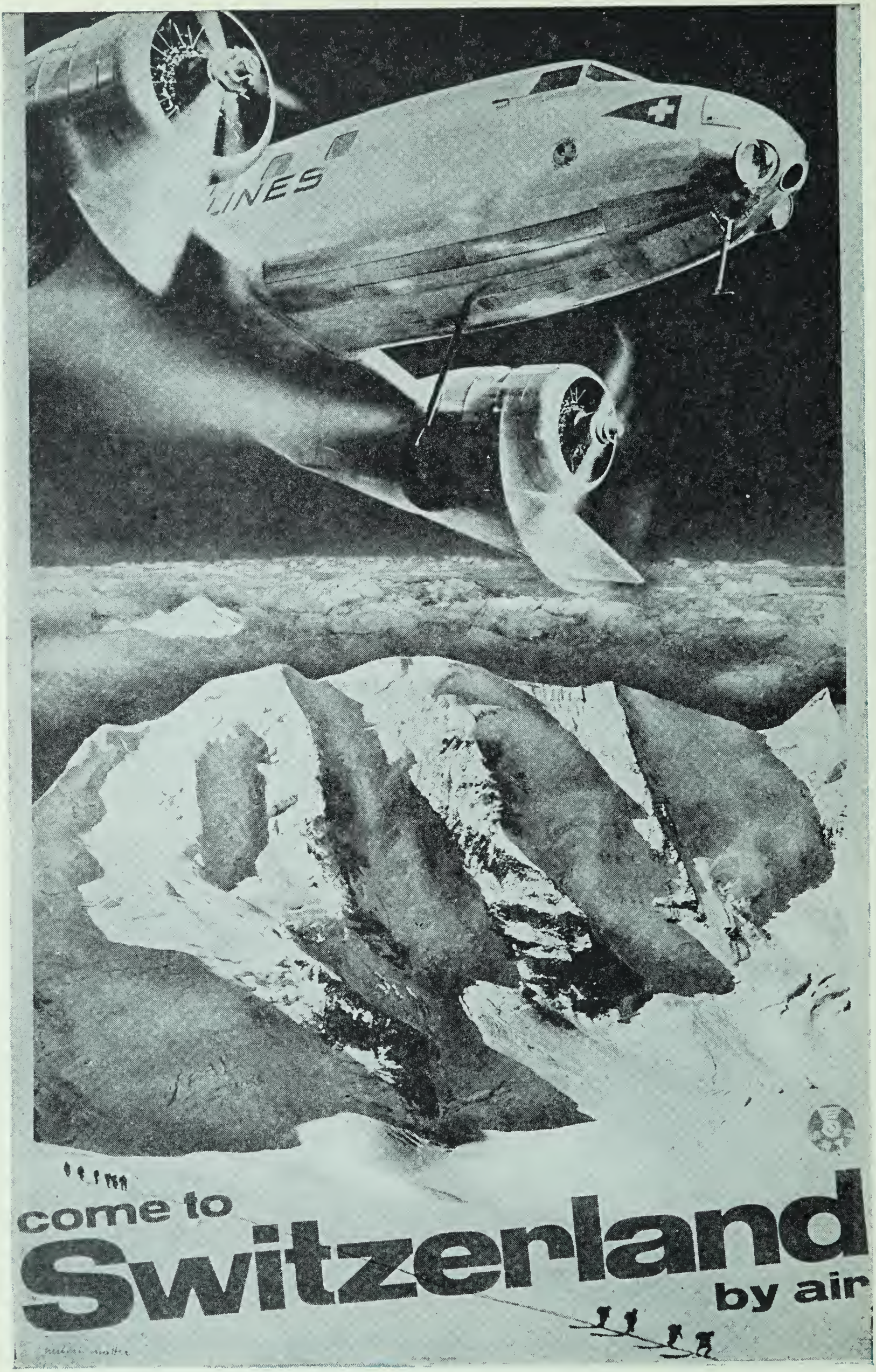
A helicopter rises straight up and comes straight down. It doesn't need much of a runway or a landing field. But in a plane you can glide from five to ten times your height; if you are ten thousand feet up, that means from ten to sixteen miles while you are looking for a field. Helicopter is another way of saying Autogiro. It rises by means of long propeller blades placed horizontally. Much experimental work has been done with the problem of landing a speeding plane *anywhere,* moving the plane straight up or down. When planes can fold their wings and drop gently to earth like a bird, the greatest thing ever known in aviation will have been accomplished.

Great things have been done with gliders, too. Guenther Groenhof glided a hundred sixty miles in one flight. One man, in a glider, has been up to a height of seven thousand feet! He was towed to a height of three thousand feet by plane, and from there, choosing his rising air

currents as carefully as our friends, the birds, he rose four thousand feet more.

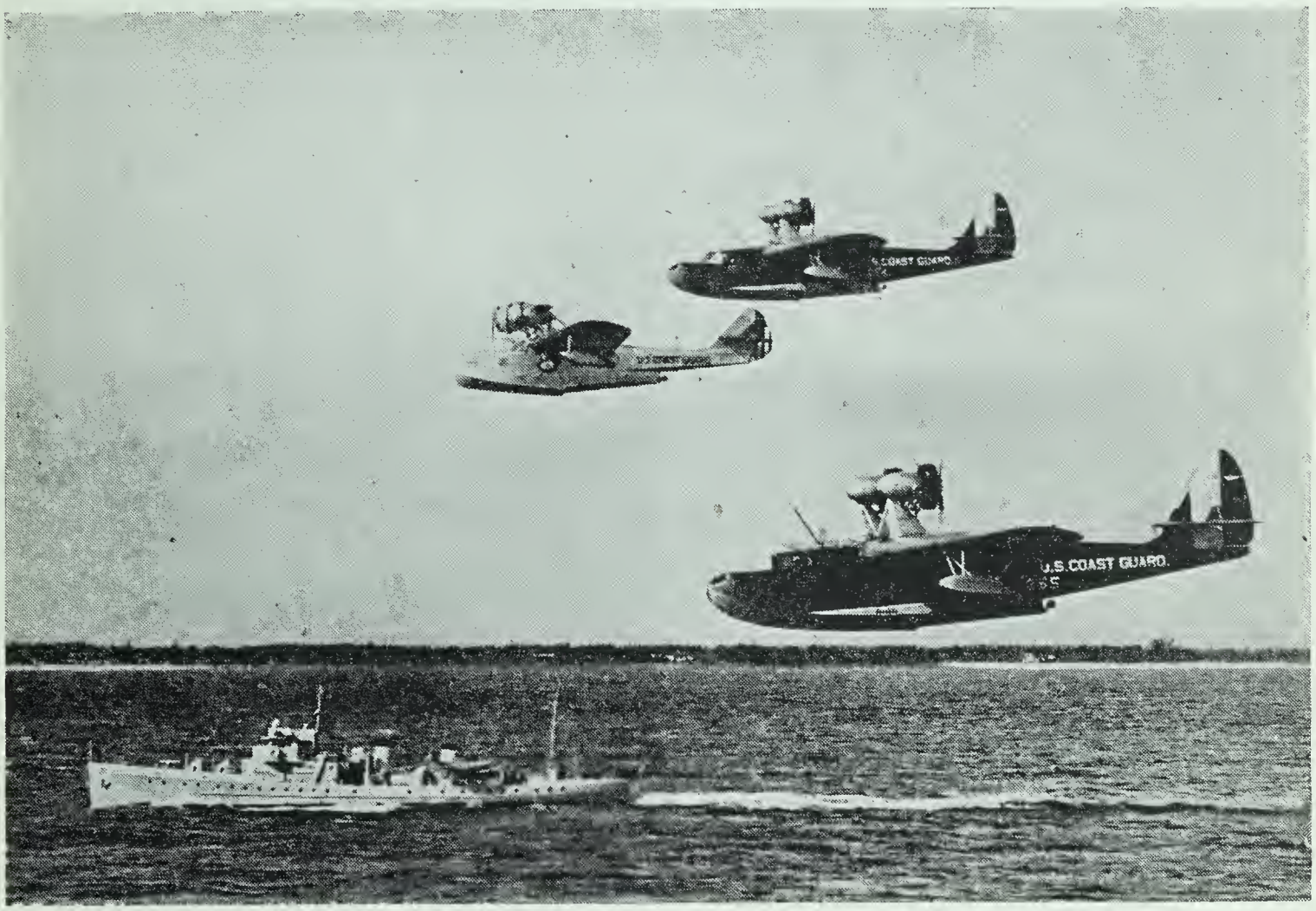
J. K. O'Meara, who made the record referred to above, and who has held the national altitude and distance records for gliders, recently soared five thousand feet above New York skyscrapers. While so doing he held a short-wave radio conversation with a wireless operator on top of one of the tall buildings. The glider in which he made the flight was

Glider Leaving the Hillside


come to
Switzerland
by air

towed from the airport to a height of thirty-five hundred feet, where the tow rope was cut and the glider allowed to rise in the strong upcurrents of warm air that kept him aloft for a flight of more than an hour.

Germany has several thousand glider pilots, but in America the sport doesn't seem particularly popular. So far as it is at present developed, the glider seems to have only limited practical value.



United States Coast Guard Planes

Meanwhile, if for no reason but its usefulness in manifold fields, the airplane is here to stay. We use it for many purposes. With it, the Russians are sowing seed—square miles of it at a time—of rye, flax, and wheat. In our own Southern States, from planes we spray the cotton—hundreds of acres of it—to protect it from the boll weevil. We spray our river valleys to exterminate mosquitoes, carry serums to the

sick, rescue people during floods, and fly over the poles, both north and south, in search of undiscovered lands.

In Canada men are flying over the frozen tundra looking for signs of copper and gold deposits which could not possibly be discovered by any other human means. In Central America, in Palestine, along the Euphrates, and in the mystic country of Ghengis Khan men are searching for hidden cities where well-nigh forgotten races have lived and loved and died.

Some day we shall see—I wonder what? Men who were strangers, strange no more; lands that were desert, blooming and sown; plains that were desolate, smiling with plenty; and everywhere people with thankful hearts, paying due homage to the speeding, glinting, daring *Spirit of the Air.*

THE CHRONOLOGY OF AVIATION

1783 June 5th. The Montgolfiers send up a smoke balloon at Annanoy.

August 27th. Professor Charles sends up a hydrogen balloon at Paris.

November 21st. Pilâtre de Rozier and the Marquis d'Arlandes are the first men to ascend in a balloon.

December 28th. The American Philosophical Society, at Philadelphia, sends a man up in a car to which forty-seven small balloons are attached.

1784 September 15th. The balloonist Lunardi ascends from the Artillery Grounds in London, carrying oars with which he proposed to guide the balloon, and accompanied by a dog, a cat and a pigeon.

1785 A Frenchman, Blanchard, and Dr. Jeffries, an American, cross the English Channel in a balloon.

1793 General Washington watches Blanchard's first ascent at Philadelphia.

1796 Sir George Cayley makes his first aeronautical experiments.

1816 Sir George Cayley builds the world's first man-carrying glider.

1836 Charles Green flies the *Great Nassau* from London to Germany, five hundred miles.

1842 William S. Henson designs his first monoplane.

1848 John Stringfellow builds the first power-driven model to achieve direct flight.

1852 Henri Giffard flies in a steam-driven dirigible.

1891 Otto Lilienthal begins experiments in glider flight.

1895 Santos-Dumont flies his first dirigible at an altitude of thirteen hundred feet.

1896 Lilienthal is killed in an attempted flight and Octave Chanute begins glider experiments in America.

Professor Langley flies his model aerodrome 3,000 feet.

1899 Wilbur Wright evolves the idea of "warping" the wings of an airplane—the forerunner of aileron control.

1900 Count Ferdinand von Zeppelin makes his first flight in a rigid dirigible.

The Wrights complete their first experimental glider, and repair to Kitty Hawk for their experiments.

1901 The Wrights build a second glider and return to Kitty Hawk.

On July 13th Santos-Dumont makes his first attempt to circle the Eiffel Tower.

On August 8th he makes a second attempt.

On October 19th he makes a third attempt, which is successful, and wins the Deutsch prize.

1902 The Wrights build a third glider, and in September and October make almost a thousand flights at Kitty Hawk.

Prior to that they had built the first wind tunnel of which the world had ever heard, and had revised most of the accepted tables of aerodynamics.

1903 October 7th. Professor Langley's first attempt to fly a power-driven machine carrying a man.

December 8th. Langley's second unsuccessful attempt.

December 17th. The Wrights, at Kitty Hawk, with a power-driven machine, fly 852 feet against a twenty-mile wind.

1905 The Wrights for the first time describe a complete circle in a flying plane.

1906 Count von Zeppelin flies his second dirigible over Lake Constance.

1907 Bleriot builds his first monoplane.

1908 Sept. 9th. Orville Wright, at Fort Myer, flies forty-five miles in one hour.

December 31st. Wilbur Wright, at Le Mans, France, flies seventy-seven miles.

Count von Zeppelin, with the rigid dirigible LZ-4, flies across the Alps, 235 miles, and return.

1909 July 19th. Bleriot flies across the English Channel.
August 22nd. The World's First Air Meet, at Rheims.
October 9th. Wilbur Wright flies up the Hudson River to Grant's Tomb, Hendrik Hudson Tercentenary.

1910 Paulhan wins the *Daily Mail* prize of £10,000 for flight London to Manchester.
Walter Wellman makes unsuccessful attempt to cross the Atlantic in the dirigible *America*.
Glenn Curtiss flies from Albany to New York City, winning *New York World* prize of $10,000.
Charles K. Hamilton flies from New York to Philadelphia and return in twenty-four hours and wins $10,000 prize.

1911 Harry W. Atwood wins prize of $10,000 for flying St. Louis to New York.

1913 Lord Northcliffe offers a £10,000 prize for the first successful nonstop transatlantic flight.

1918 The United States air mail is established between Washington and Philadelphia.

1919 May 16-17th. The NC-4 flies from Newfoundland to the Azores.
June 14-15th. Alcock and Brown fly from Newfoundland to Ireland.
July 2nd. The R-34, a British dirigible, flies from Edinburgh to New York. Returns in a few days for flight to England.

1923 May 2nd-3rd. First nonstop transcontinental flight, New York to San Diego, Lieuts. Kelly and Macready.

1924 First round-the-world flight, U. S. Army planes. Flying time 371 hours.
The Los Angeles, rigid airship, flies Friedrichshafen to Lakehurst, 5066 miles, in command of Dr. Hugo Eckener.

1926 May 9th. Lieutenant Commander Richard E. Byrd and Floyd Bennett, U. S. N., make first flight over the North Pole.
May 11th-14th. The semirigid airship *Norge*, carrying Roald Amundsen and Commander Nobile, crosses the North Pole.

1927 May 20th. Charles A. Lindbergh makes his famous flight, New York to Paris, the first nonstop flight from the United States to Europe.
June 28th. Nonstop flight from Oakland to Honolulu, Lieuts. Maitland and Hegenberger, U. S. A.

1928 April 12th-13th. The *Bremen* makes the first westbound airplane flight across the Atlantic, Captain Koehl, Captain Baron von Huenefeld and Major Fitzmaurice.

1928 May 31st. Captains Kingsford-Smith and Ulm fly the *Southern Cross* from Oakland, California, to Brisbane, Australia, in nine days.

1930 Captain Frank Hawks makes transcontinental flight, New York to Los Angeles, in 12 hours and 25 minutes.

1931 Professor Auguste Piccard makes world's altitude record of 52,426 feet. Wiley Post and Harold Gatty make a round-the-world flight in 8 days, 15 hours and 51 minutes.

1932 Amelia Earhart Putnam flies across the Atlantic, Harbor Grace, Newfoundland, to Londonderry, Ireland, in 15 hours and 18 minutes.

1933 Colonel Roscoe Turner flies from Burbank Field, California, to New York City in 10 hours, 2 minutes and 57 seconds.

Wiley Post flies around the world alone, over virtually the same route as that flown by himself and Gatty. He reduced the record to 7 days, 18 hours and 49½ minutes.

1935 The China Clipper inaugurates regular transpacific service, San Francisco to Manila, November 22nd.

1936 October 28th-30th. Captain James B. Mollison flies New York to Harbor Grace, Newfoundland, and thence to Croydon, England, 19 hours 59 minutes.

GLOSSARY

aerodromes (ā′ẽr-ȯ̊-drōms′) — The name given by Dr. Langley to his flying machines, the word airplane not yet having been created.

aerodynamics (ā′ẽr-ȯ̊-dī-năm′ĭks) — The science which treats of the action of air when force is applied to it.

aeronaut (ā′ẽr-ȯ̊-nôt) — One who operates an airship or balloon. One who flies through the air.

aeronautics (ā′ẽr-ȯ̊-nô′tĭks) — The art or science of operating aircraft.

aileron control (ā′lẽr-ŏn kŏn-trōl′) — Control of the balance or equilibrium of a plane by the use of ailerons.

ailerons (ā′lẽr-ŏns) — Flaps attached to or fitted into the trailing edge of the wings by means of hinges. With the ailerons the pilot may control the plane's equilibrium by raising or lowering, as required.

aircraft (âr′krȧft′) — Any weight-carrying device or machine for navigation in the air.

airplane (âr′plān′)	A heavier-than-air, power-driven flying machine.
airplane carrier (âr′plān′ kăr′ĭ·ēr)	A seagoing vessel equipped for the storage of airplanes. On the deck of a carrier planes can land or take off in flight.
airport (âr′pōrt′)	A field or station equipped for the arrival and departure of airplanes. The equipment includes hangars, machine shops, radio equipment, dispatcher's office, and accommodations for the arrival and departure of passengers, mail, and express.
airship (âr′shĭp′)	A term used to describe dirigible flying craft that are lighter than air.
air-speed indicator (âr-′spēd ĭn′dĭkā′tēr)	The indicator on a plane's instrument board that shows the speed with which the air is passing over the plane. This does not usually mean the speed with which the plane is passing over the earth's surface, as it may be delayed by head winds or hastened on by tail winds, the speed of which is included in the figures shown on the indicator.
air stream (âr′strēm)	The air currents passing over and under the rounded leading edge of the airplane wing.
air tables (âr tā′b'ls)	Tables showing in scientific terms the action of air upon a moving object.
airway (âr′wā′)	A recognized route for planes, usually equipped with radio beam, fully lighted, and supplied with terminal airports and intermediate emergency landing fields.
altimeter (ăl·tĭm′ĕ·tēr)	An indicator on the instrument board of a plane which shows the height of the plane above sea level. Note that this differs from the altitude above the ground. The plane may be flying only one thousand feet above a nine thousand foot mountain, but the altimeter will register ten thousand feet; the pilot must thus deduct the elevation of the earth above sea level at the point he is traversing to get his height above land.
ammeter (ăm′mē′tēr)	An instrument for measuring electric current.
angle of incidence (ăng′g'l ŏv ĭn′sĭ-dĕns)	The angle between the longitudinal direction of the plane and the direction of flight. The nose of the plane may be pointed slightly upward, while the direction of the plane is straight ahead. The angle between the two is the angle of incidence.

artificial horizon
(är′tĭ·fĭsh′ăl hŏ·rī′z'n)
The indicator on the instrument board which shows the direction in which the plane is inclined in reference to the horizon of the earth.

autogiro
(ô′tŏ·jī′rō)
A heavier-than-air machine on which the wings are supplemented by rotating blades that supply the power to rise.

bailing out
(bāl′ĭng out)
Leaving the plane by means of a parachute.

bank
(băngk)
To bank a plane is to incline the outer wing upward to prevent skidding when making a turn. The turn and bank indicator shown on page 113 shows the pilot the degree of curve the plane is traveling and the amount of banking that is required.

beam
(bēm)
The directional radio beam on which planes travel on the Federal Airways.

benzene
(bĕn′zēn)
A colorless liquid, highly inflammable, obtained from coal in the process of making coke or coal gas.

biplane
(bī′plān′)
An airplane with two pairs of wings, one placed above the other.

blimp
(blĭmp)
A small, nonrigid, dirigible airship. An elongated, power-driven balloon.

camber
(kăm′bĕr)
The slight convexity or rise to the curve of an airplane wing, or any other curved surface. *Upper camber* is the camber of the top surface of the wing. *Lower camber* is the curve of the under surface of the wing.

cambered wing
(kăm′bērd wĭng)
A wing bearing a surface that is slightly curved.

Cathay
(kă·thā′)
A name applied to China, especially in the Middle Ages.

ceiling zero
(sēl′ĭng zēr′ō)
A term indicating that on account of fog or other causes the visibility is poor or is quite absent not only at a height, but as far down as the ground level, leaving no ceiling under which the pilot can see to direct his plane.

density
(dĕn′sĭ·tĭ)
Compactness.

directional beam
(dĭ·rĕk′shŭn·ăl bēm)
(See beam.)

directional gyro
(dĭ·rĕk′shŭn·ăl jī′rō)
A mechanical compass that is not affected by outside influences.

dirigible
(dĭr′ĭ·jĭ·b'l)
An airship that is steerable. It may be nonrigid, without an interior frame, like a blimp; semirigid; or rigid, with an interior framework of metal, like a zeppelin.

drag
(drăg)
(See drift.)

drift
(drĭft)
The lateral, or sideways movement of a plane, due to air currents. Formerly called *Drag*.

elevator
(ĕl′ĕ·vā′tĕr)
A movable auxilliary flap, or rudder, at the tail of the plane, fixed in a horizontal position, that raises or lowers the nose of the plane. The rudder, fixed vertically, controls its lateral direction. The elevator is controlled from the instrument board by small handles or levers known as the elevator flap adjusters.

glider
(glīd′ẽr)
An airplane without a motor, depending upon air currents for its movement.

gyropilot
(jī′rō·pī·lŭt)
An automatic control of a plane by which its actions may be directed without the intervention of the pilot.

hangar
(hăng′ẽr)
A building for the shelter of airplanes or airships.

helicopter
(hĕl′ĭ·kŏp′tẽr)
A form of aircraft that is supported in the air solely by the downward current of air created by its propellers, as in the autogiro.

helium
(hē′lĭ·ŭm)
A natural gas found in certain minerals and in other natural gases. Because of its noninflammable nature it is separated from natural gas for use in balloons and airships. It is twice as heavy as hydrogen, but its lifting power is almost as great and its loss is less rapid.

horizon
(hŏ·rī′z'n)
(See artificial horizon.)

hydrogen
(hī′drŏ-jĕn)
An inflammable gas that is lighter than any other known substance.

lift
(lĭft)

The force opposed to gravity which a plane produces and which thereby keeps the plane from falling.

monoplane
(mŏn′ō·plān)

An airplane with but one main supporting surface, supplied by one pair of wings.

nose dive
(nōz dīv)

A straight-down flight toward the nearest point on the earth. A head-on dive.

parachute
(păr′ȧ·shōōt)

A folding, umbrellalike contrivance that is used for descending from an airplane in an emergency. As the umbrella opens, it breaks the speed of the descent until the aviator reaches the ground at comparatively slow speed.

pitch control
(pĭch kŏn·trōl′)

The effectiveness of propeller blades depends in great degree upon the angle at which they turn. Changes in this angle, or pitch, to meet air conditions, are made from the cockpit through the adjustment of levers or handles on the instrument board.

pontoons
(pŏn·tōōns′)

Boatlike skids or shoes, attached below the fuselage of a seaplane, on which the plane lands when it strikes the water, and on which it remains afloat while at rest. They take the place of the wheels used on land planes.

propeller blades
(prō·pĕl′ĕr blādz)

The blades which, revolving at a rate of speed, cleave the air and draw the plane after them.

propeller shaft
(prō·pel′ĕr shȧft)

The revolving shaft connecting the engine with the propeller blades.

radial engine
(rā′dĭ·ăl ĕn′jĭn)

An internal-combustion engine, having the cylinders arranged in a circle around the crankshaft. When the cylinders revolve around the shaft the engine is called a *rotary engine*. When the cylinders are stationary and the crankshaft revolves it is a *fixed radial*, or simply a *radial engine*.

radio beacon
(rā′dĭ·ō bē′kŭn)

A radio transmitting station that sends Morse signals along a directional beam, by which signals the pilot may determine at all times his direction and position.

radio beam
(rā′dĭ·ō bēm)

The fan-shaped path of radio waves over which Morse signals are repeated constantly from the radio beacon, fixing the direction to be taken by the moving plane.

radio compass
(rā′dĭ·ō kŭm′pȧs)

A direction finder used in navigating an airship or airplane.

radio control
(rā′dĭ·ō kŏn·trōl′)

Control of the steering mechanisms of a plane from a distance, by the use of radio waves, instead of control by the pilot from the cockpit of the plane. (See gyropilot.)

Radio Direction Finder
(rā′dĭ·ō dĭ·rĕk′shŭn fīn′dĕr)

(See radio beam and radio beacon.)

radiotelephone
(rā′dĭ·ō·tĕl′ē·fōn)

The telephone system by which communication between the pilot and the landing field and between himself and other pilots is maintained.

retractable wheels
(rē·trăkt′ă·b'l hwēls)

The wheels of an airplane that can be retracted or drawn up after it leaves the ground. This is done in order to avoid the drag caused by the wheels if they are allowed to hang down into the air currents created by the moving plane.

rheostat
(rē′ŏ·stăt)

A regulator by which lights may be dimmed or strengthened.

seaplane
(sē′plān′)

Any airplane designed to take off from and alight on the water. A *flying boat* is a seaplane the hull of which serves as fuselage for the plane and also as its support when in the water.

stratosphere
(strā′tŏ·sfēr)

The portion of the atmosphere that lies above the height of eleven kilometers—about seven miles. The temperature here changes but little, there are no winds, and clouds of water do not form.

substratosphere
(sŭb·strā′tŏ·sfēr)

The atmospheric area just beneath the stratosphere in which much flying is now done.

switch bank
(swĭch băngk)

A bank or row of buttons or keys on the instrument board of the plane by means of which the board may be connected or disconnected with the various mechanisms for navigation and operation.

tachometer
(tă·kŏm′ĕ·tĕr)

A dial plate that indicates the number of revolutions per minute of an airplane engine.

tail spin
(tāl spĭn)

A nearly vertical spin, nose down, around a circle of very small radius.

thermocouple
(thûr′mŏ·kŭp″l)

A device on the instrument board of the plane indicating the temperature of the engine cylinders.

trailing edge
(trāl′ĭng ĕj)

The rear edge of the wings of a plane—the edge on which the ailerons are installed.

turn and bank indicator
(tûrn ănd băngk ĭn′dĭ·kā′tĕr)

(See bank.)

vacuum
(văk′ū·ŭm)

A space from which the air has been withdrawn entirely, or, as in the streamline over an airplane wing, almost entirely withdrawn to form a partial vacuum.

wind tunnel
(wĭnd tŭn′ĕl)

A tunnel or passage used in aeronautical laboratories, through which air is forced at various known speeds and directions to determine its effect upon an airplane of given design. Small models of the planes are usually used. There are also in use elaborately equipped tunnels that are large enough to admit full-sized planes.

zeppelin
(zĕp′ĕ·lĭn)

Any rigid airship of the type first constructed by Ferdinand, Count von Zeppelin.

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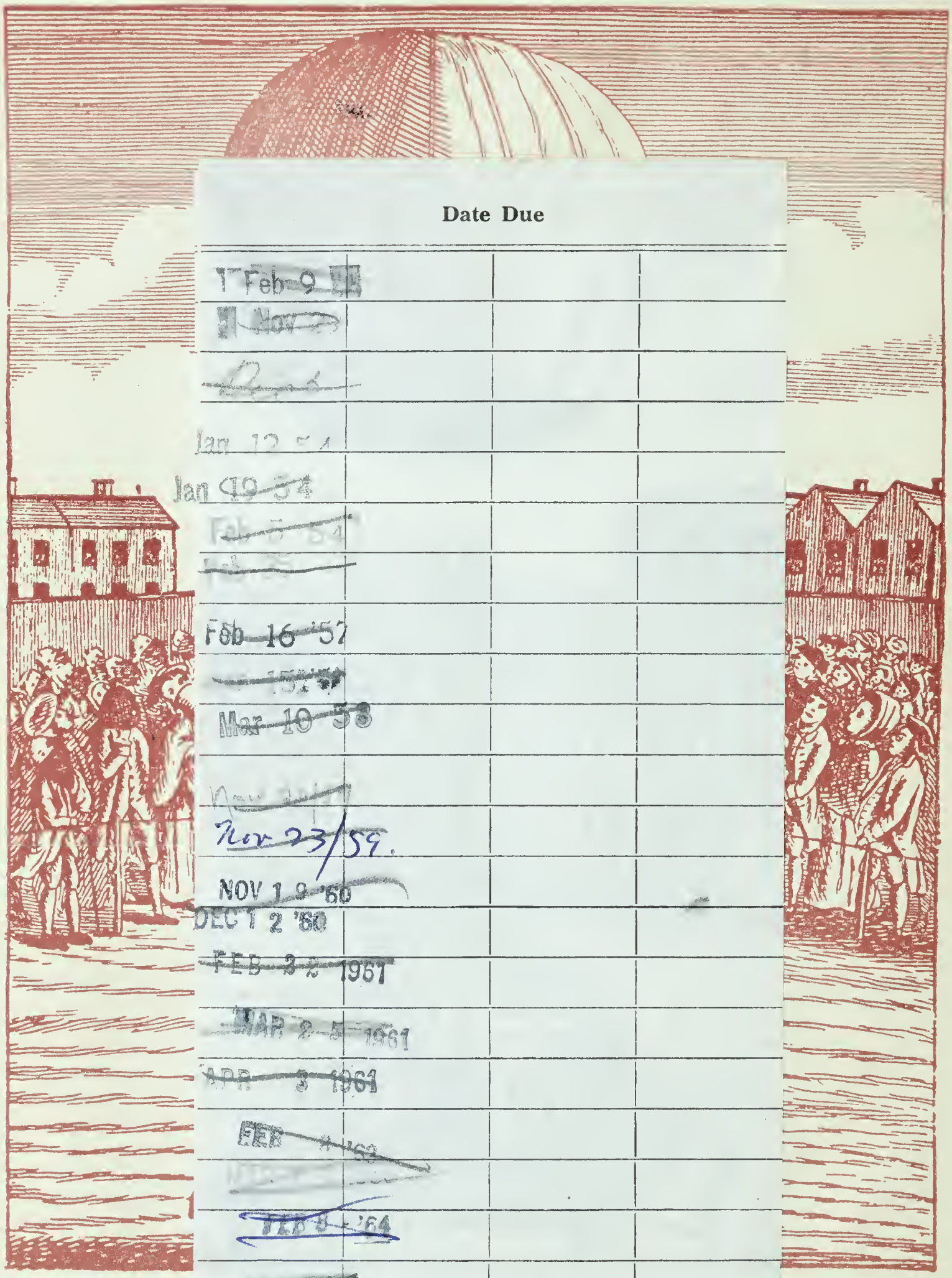

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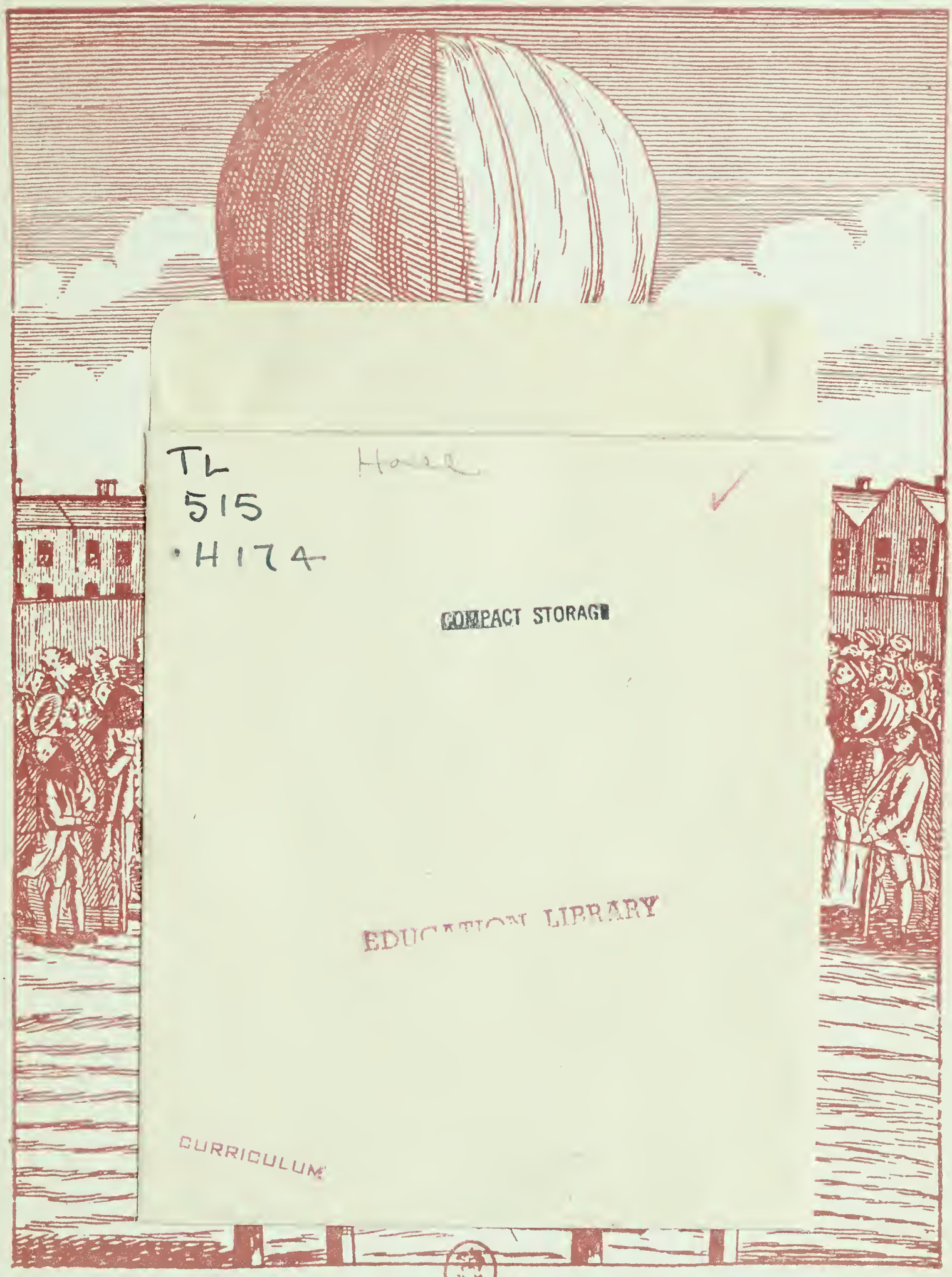

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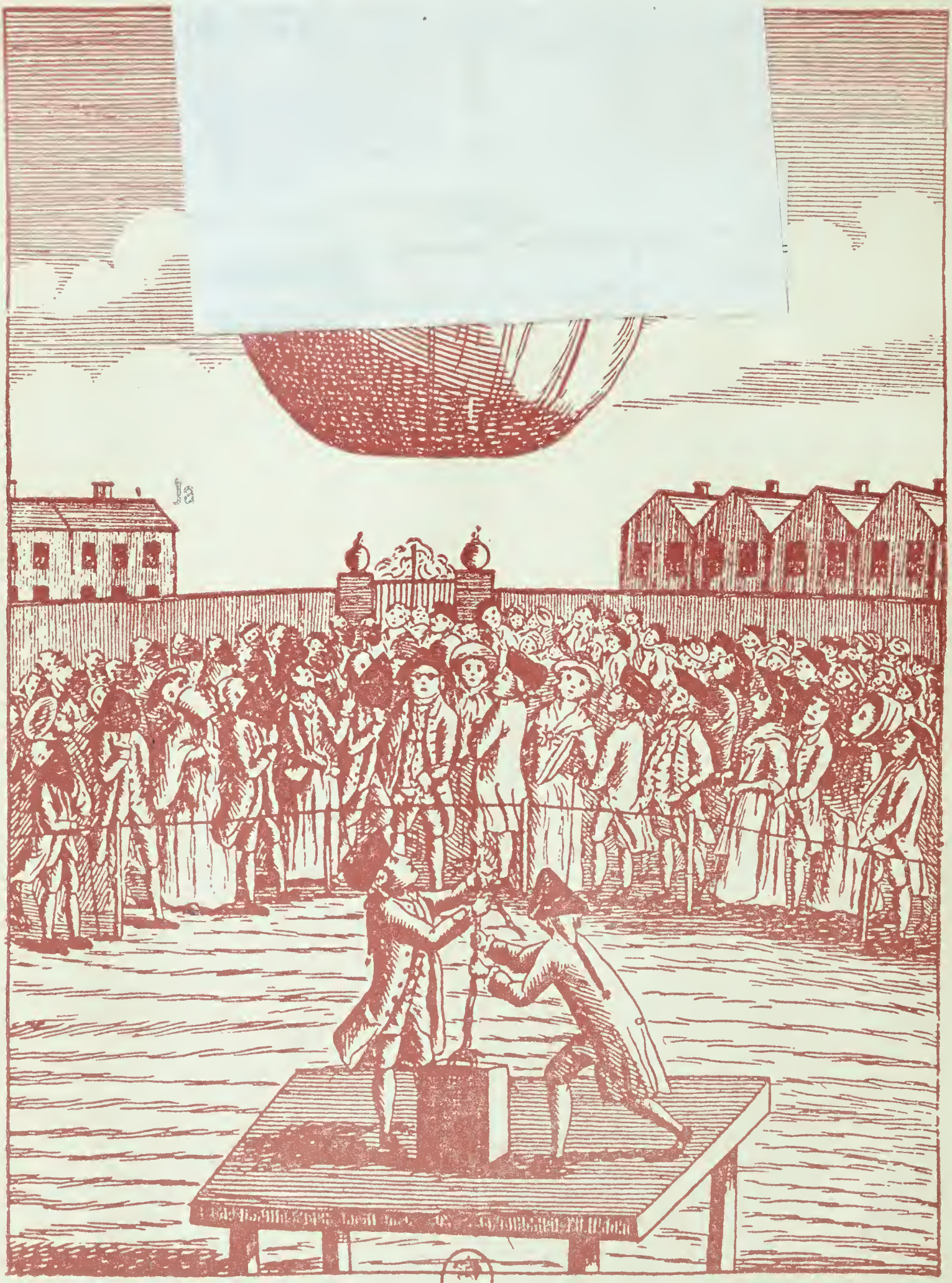

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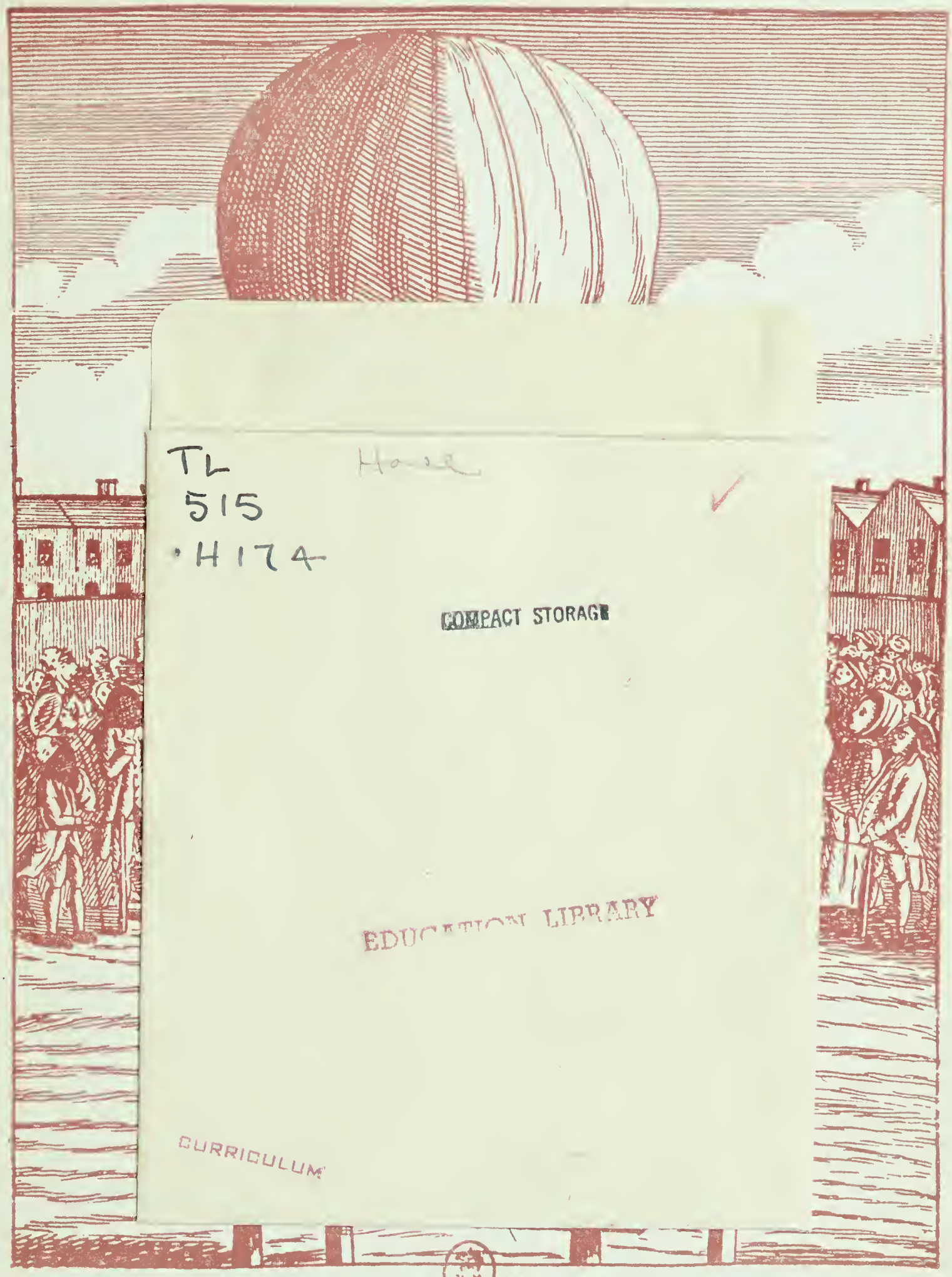

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